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THE USE OF ORGANIC POLYELECTROLYTE FOR OPERATIONAL IMPROVEMENT OF WASTE TREATMENT PROCESSES

John J. Wirts, et al

Cleveland, Ohio

May 1969

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THE USE OF ORGANIC POLYELECTROLYTE FOR OPERATIONAL IMPROVEMENT OF WASTE TREATMENT PROCESSES

Prepared For
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
By
CITY OF CLEVELAND, OHIO

GRANT NO. WPRD 102-01-68

May, 1969

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John J. Wirts
Project Director

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PREFACE

Major support funds for this development project were provided by the Department of the Interior, Federal Water Pollution Control Administration. We are indebted to the F.W.P.C.A. for their very fine assist and particularly the Chicago F.W.P.C.A., Great Lakes Region Office for the services of Mr. Ralph G. Christensen, Program Representative.

The ultimate test method is full plant scale which was used in this demonstration. Existential truth is approached through all the real happenings in a major plant. Fitted to the four seasons the real events, the power failures, the industrial "accidents," the changing shifts, the changing personnel, the preventative maintenance program have an impact on productivity and evaluation. This is as it should be, a real life demonstration.

Our objective is to bend aspects of nature and society toward an environment suitable for the comfort of man - and the only reward for a sound analysis is to have done it.

ABSTRACT

Federal Water Pollution Control Administration - City of Cleveland demonstration of Raw Waste Flocculation Process conducted at Cleveland Easterly showed significant improvements in plant operations, such as (1) increase in SS and BOD removals in primary treatment, (2) more efficient operation of the secondary treatment process, (3) increase in sludge pumpability in a 13 mile force main, and (4) cost savings approaching cost of polymer treatment. A detailed cost analysis showed that significant capital costs savings could result if this process were practiced. A completely automated polymer dispersal and addition system was developed.

I. SUMMARY OF FINDINGS

A. CONCLUSIONS

1. A completely automated polymer dispersal and metering system can be provided at relatively low cost.

2. Plant performance improvement, as measured by a 72% increase in primary suspended solids removal and a 50% increase in primary BOD removals, was attained during polymer treatment.

3. The usually highly variant primary treatment efficiency pattern is smoothed out to a large extent during polymer treatment.

4. By increasing primary removal efficiencies during polymer application, a significant reduction in waste activated sludge was realized. A reduction in w/a tonnage of 34% and a 20% decrease in w/a volume were noted.

5. A stable, efficiently-settling biological floc was produced even though the BOD feed to aeration was predominantly soluble with raw sewage flocculation.

6. A 22% reduction in the quantity of air supplied to aeration was noted during raw sewage flocculation. Dissolved oxygen in the aeration system was higher during polymer treatment.

7. A reduction in effluent SS to Lake Erie of 31% (4 tons/day) and a BOD reduction of 32% (5 tons/day) were attained during polymer addition.

8. Primary sludge solids concentration increased a small amount during polymer flocculation.

9. Total sludge volume and total sludge tonnage decreased during raw waste flocculation.

10. An increase in the concentration of total sludge solids delivered to Cleveland Southerly was noted during polymer treatment.

11. Although a decrease in primary sludge viscosity was apparent during polymer addition, no significant pumpability increase accompanied this viscosity change.

12. The more favorable rheological characteristics of a 2:1 blend of waste activated to primary sludges vs. the behavior of separate phases led to an important operation change that affected sludge pumpability to a large extent.

13. Polymer activity in raw sewage appears to be related to the concentration of total soluble metals, and can be related to Ca, Mg, and Fe species.

14. A blower power cost savings of over $3,300 per month was attained during raw sewage flocculation.

15. A total direct cost analysis of polymer versus no polymer treatment, as measured by the cost to remove a unit of pollutant, indicates that the increased removals attainable with raw waste flocculation and all related operational cost savings come relatively close to equaling the cost of polymer treatment.

16. A hydraulically overloaded waste treatment plant can realize much more efficient operation through raw waste flocculation, with little capital expenditures necessary to implement the process.

17. Based on the total cost of money to supply extra primary tank capacity to equal the performance attained with polymer treatment, a total cost of approximately $314,000 per year will be required. Polymer costs are estimated at $160,000 per year.

B. RECOMMENDATIONS

It can be concluded with confidence that raw waste flocculation can greatly aid the efficiency and operation of a secondary treatment plant. Acceptance in the past has been limited by economic considerations. The cost data developed in this study indicate a very favorable polymer cost versus capital cost to achieve the same degree of treatment as with polymers. The cost-benefit ratio pertaining to costs per unit of pollutant removed is also favorable. The possibility of raw waste flocculation delaying or replacing capital expansion will become increasingly attractive since the tendency in the chemical industry has been lower chemical costs, while at the same time construction costs are rising at a rate of over 5% per year.

It is thus recommended that municipal waste treatment officials and consulting engineers carefully review this study when considering alternative treatment methods. In light of the favorable economic and performance data presented, such review is justified.

It is also recommended that a study of sludge force main pumpability be made, utilizing various additives such as synthetic polyelectrolytes and dispersants. These would be added directly to the force main.

C. COSTS

The costs related to the benefits attributed to polymer treatment are of prime importance to this study. A short summary of this cost data is presented here.

1. The yearly capital costs, including interest and amortization over 25 years, for debt retirement of primary tankage to equal the performance of the raw waste flocculation polymer is about $314,000 per year. It is estimated that raw waste flocculation via polymer treatment would cost $150,000 per year, thereby indicating a considerable yearly savings for the polymer treatment mode.

2. The total direct cost of primary and secondary treatment per ton of pollutant removed is summarized as follows:

Tons of Specific Pollutant Removed	Control Period	Polymer Demonstration Period
SS	$31.80	37.82
BOD	$50.11	50.57

3. The total direct costs in cents per 1000 gallons of waste treated are as follows. It must be remembered that these are only direct costs, and do not include facility and general and administrative costs.

	Control Period	Polymer Demonstration Period
Primary	0.225¢/1000 gal.	0.560*
Secondary	0.687	0.593
Total	0.912	1.153

*Includes 0.335¢/1000 gal. polymer costs

II. INTRODUCTION

A. NEED FOR PROJECT

The chemical industry has developed new materials such as the water soluble organic polyelectrolytes and laboratory testing has shown that certain polymers have good coagulating action of sewage solids which can improve sewage purification. A need for improved process operation at the Cleveland Easterly plant has developed from both a hydraulically overloaded system and from the fact that all Easterly sludge is pumped approximately 13 miles to the Cleveland Southerly plant for processing. It is believed that the use of polyelectrolytes will 1) reduce the SS and BOD load on the activated sludge unit, 2) reduce the SS and BOD content in the final effluent, and 3) provide a sludge which will have improved pumpability characteristics.

B. PURPOSE (Objective)

The objectives are to determine the increased purification attainable in a full scale activated sludge plant through the use of polyelectrolytes in the waste treatment process and to show where and how the use of these relatively new polyelectrolyte products can make it economically possible to upgrade the effective operation of any established waste treatment facility. If successful, the use of polyelectrolytes in this trial will have established a new method of "Instant Pollution Abatement Through Operational Improvement."

The specific objectives are listed as follows:

1. Determine the increased removal of BOD, COD, SS, nitrogen and phosphate in primary treatment employing raw sewage flocculation.

2. Determine the increase in underflow densities and volume of primary solids.

3. Determine any decrease in production of secondary sludge due to a reduction in organic loading of secondary plant.

4. Determine the increase in BOD, COD, SS, nitrogen and phosphate removal and chlorine requirement through secondary portion of the plant.

5. Determine the secondary sludge settling characteristics and concentrations.

6. Determine the decrease in sludge viscosity and subsequent improvement in pumpability of both raw and waste activated sludge due to raw sewage flocculation.

7. Determine the decrease of friction loss in the 13 mile force main due to the presence of polyelectrolyte in the sludge.

8. Determine optimum loading (lbs. BOD/lbs. MLSS) of activated sludge portion of the plant to effect most efficient operation and best treatment.

C. DURATION OF PROJECT

The demonstration period officially started on February 12, 1968. The seven day pretrial period was run the previous week to establish proper polymer dosage and optimum addition point. The testing officially ended on December 1, 1968. This final report thus includes data from February 12, 1968, up to and including that of November 30, 1968.

D. PLANT DESCRIPTION

The Cleveland Easterly Pollution Control Center at Cleveland, Ohio, provides both primary and secondary treatment to the City wastes and is of the fine bubble activated sludge design. Its 1931 basis of design is 123 MGD average dry weather flow, and

approximately 225 MGD maximum flow with storm water. The plant site, office, and laboratory building are located on the northeast limits of the city and sewage flow to the Easterly plant is fed through two different interceptor systems. Of the total flow entering the Easterly Center, about 70% is gravity discharged by the Main system interceptor and the remainder is through the Collingwood interceptor, some of which is pumped into the plant. Specifically, the Easterly Center provides screening, comminution, grit removal, pre-aeration, primary sedimentation, activated sludge, final settling, and chlorination. Raw sludge, grease, and waste activated sludge are pumped through a 12 inch force main approximately 13 miles to the Cleveland Southerly Plant where the mixture undergoes digestion, vacuum filtration, and incineration. A schematic diagram of the plant appears as Figure 1 following.

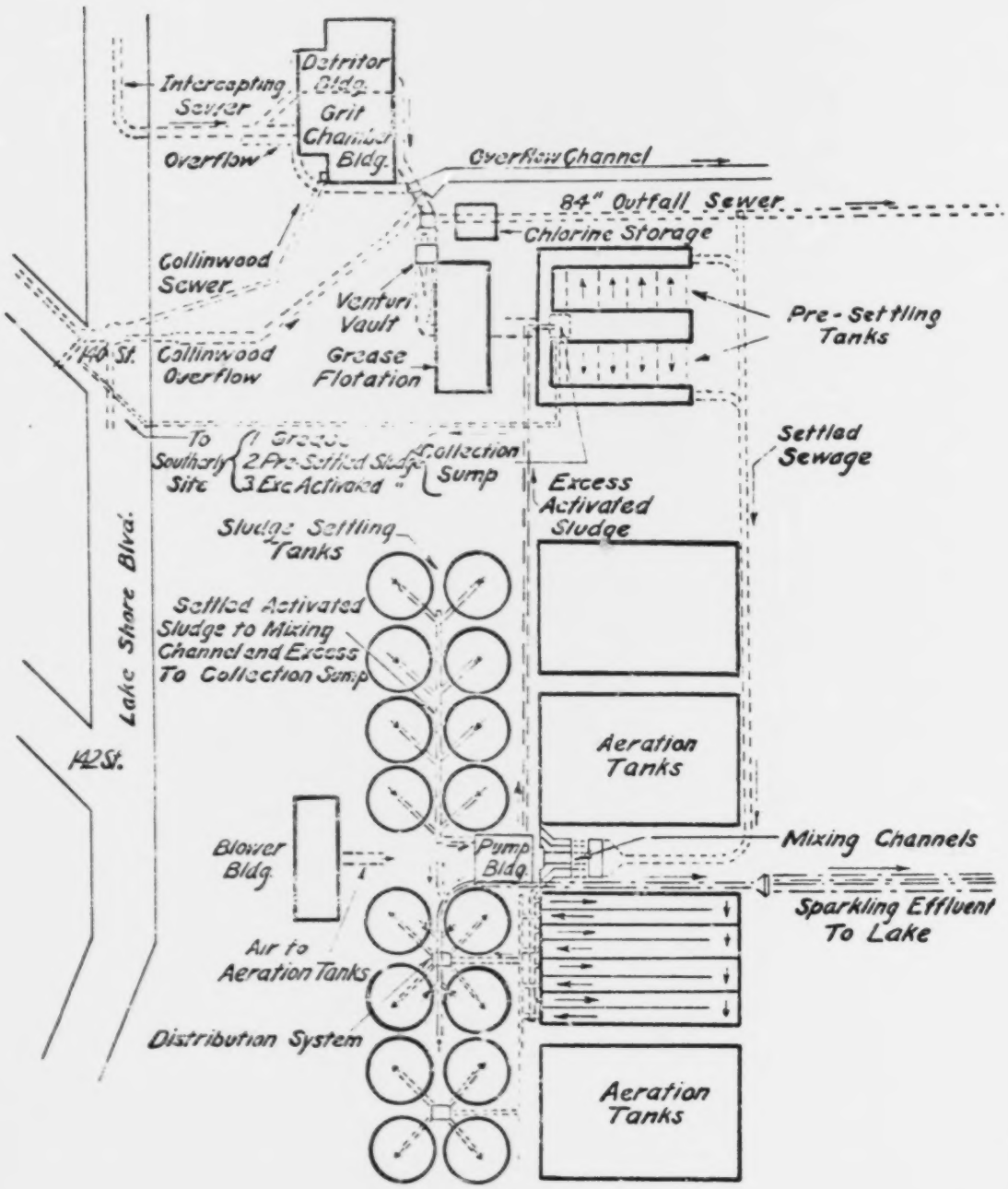


FIGURE 1

Easterly Sewage Treatment Works
General Operation Plan

III. CONDUCT OF STUDY

A. MATERIALS AND EQUIPMENT

Based on prior years of experience it was felt that The Dow Chemical Company was well qualified to participate in this Research and Development Project, and therefore Dow participation was obtained. Extensive laboratory polymer evaluations at the Easterly Center and competitive contracts for selecting a chemical supplier for a raw sewage flocculation trial at the Cleveland Westerly Sewage Treatment Plant led to this decision. In addition, the capability and willingness of the chemical supplier to provide qualified technical assistance in the start-up phase and during trial operation, and the type and quantity of equipment that the chemical supplier would be willing to furnish for the trial, particularly automatic polymer solution make-up equipment, led to the selection of Dow.

It was agreed that Dow would supply Purifloc® A-23 anionic polyelectrolyte on a delivered price per pound basis of $1.615. In addition, Dow agreed to provide, free of charge, sufficient Purifloc A-23 for a seven day pretrial to determine exact dosage requirements and the proper addition points for the chemical, and also automatic polymer dispersing equipment (Hague disperser) and chemical proportioning pumps. Complete design specifications for the automatic polymer programming instrumentation were also supplied, free of charge, by Dow. Dow engineers provided on-site technical supervision during this seven day pretrial period, and also during the entire period of polyelectrolyte addition to the raw waste stream. Estimated value of his contribution is in excess of $20,000.

The goal of the equipment portion of the project was to provide a completely automatic polymer feed system. This consisted of two separate problems, (1) an automatic polymer dispersal (make-up)

system, and (2) metering equipment to automatically dispense dispersed polymer in proportion to the raw sewage flow.

The flocculant used in this study, Purifloc A-23, is an organic anionic polyelectrolyte designed specifically for raw sewage flocculation. Its basic structure may be depicted as an essentially linear chain of acrylamide monomeric units. Hydrolysis of the amide to an acid salt form produces an end product of specific electronegative charge with a very high molecular weight. Purifloc A-23 is supplied as a white granular material in 50 pound bags.

To automatically make up a proper polymer solution, a skid-mounted automatic polymer disperser, manufactured by the Hague Equipment Company, Inc., Evansville, Indiana, was installed. This skid provides automatic make-up of polymer solution at the rate of 25 gpm of a 0.25% by weight solution. The on-off cycle of this skid is controlled by a float switch mechanism mounted in the 1100 gallon polymer holding tank. (The tank happened to be rubber lined but the lining is not essential.) The polymer disperser provides complete wetting of the polymer particles and then solution of the wetted particles to provide a homogeneous polymer solution, all automatically. Secondary mixing is provided by a 3/4 HP Lightnin mixer located on the tank. Storage for about 250 pounds of polymer is provided in the feed hopper.

Much plant scale experience has shown that raw sewage polymer demand is best supplied by feeding liquid polymer in proportion to the waste flow. Although a definite demand is probably exerted by the raw sewage solids, no accurate measurement of this demand is presently possible. Several ideas for such measurement have been tried unsuccessfully, including streaming current and turbidimetric measurements. It was thus decided that polymer should be fed in proportion to the raw sewage flow. From the period February 12,

1968 until April 19, 1968, polymer was proportioned utilizing an HL-156 (1-1/4") Viking gear pump with a 1 HP variable speed D.C. electric drive. Pump speeds were reset hourly according to raw sewage flow variations.

Approval to purchase electronic instrumentation for automatic polymer feed was requested and received in December, 1967. This system was constructed by the Easterly staff from schematic design by The Dow Chemical Company's Engineering, Instrumentation Department. A schematic of this system is seen in Figure 2. It includes a differential pressure cell that develops a milliamper signal in proportion to the flow (ΔP) through a raw sewage Venturi tube, a square root extractor to linearize the developed signal, a ratio relay station to multiply the linear signal so that a predetermined dosage is maintained, and a 1 HP D.C. variable speed motor that is controlled by this developed milliamper signal. Either manual control mode or automatic control mode is available with this system. A Jabsco Model 6400 (1-1/4") neoprene impeller pump was connected to this motor. This system reached operational status April 19, 1968, and was operational throughout the project. Automatic variance of the polymer solution in proportion to the raw sewage flow was thus attained. An itemized part list for this instrumentation follows:

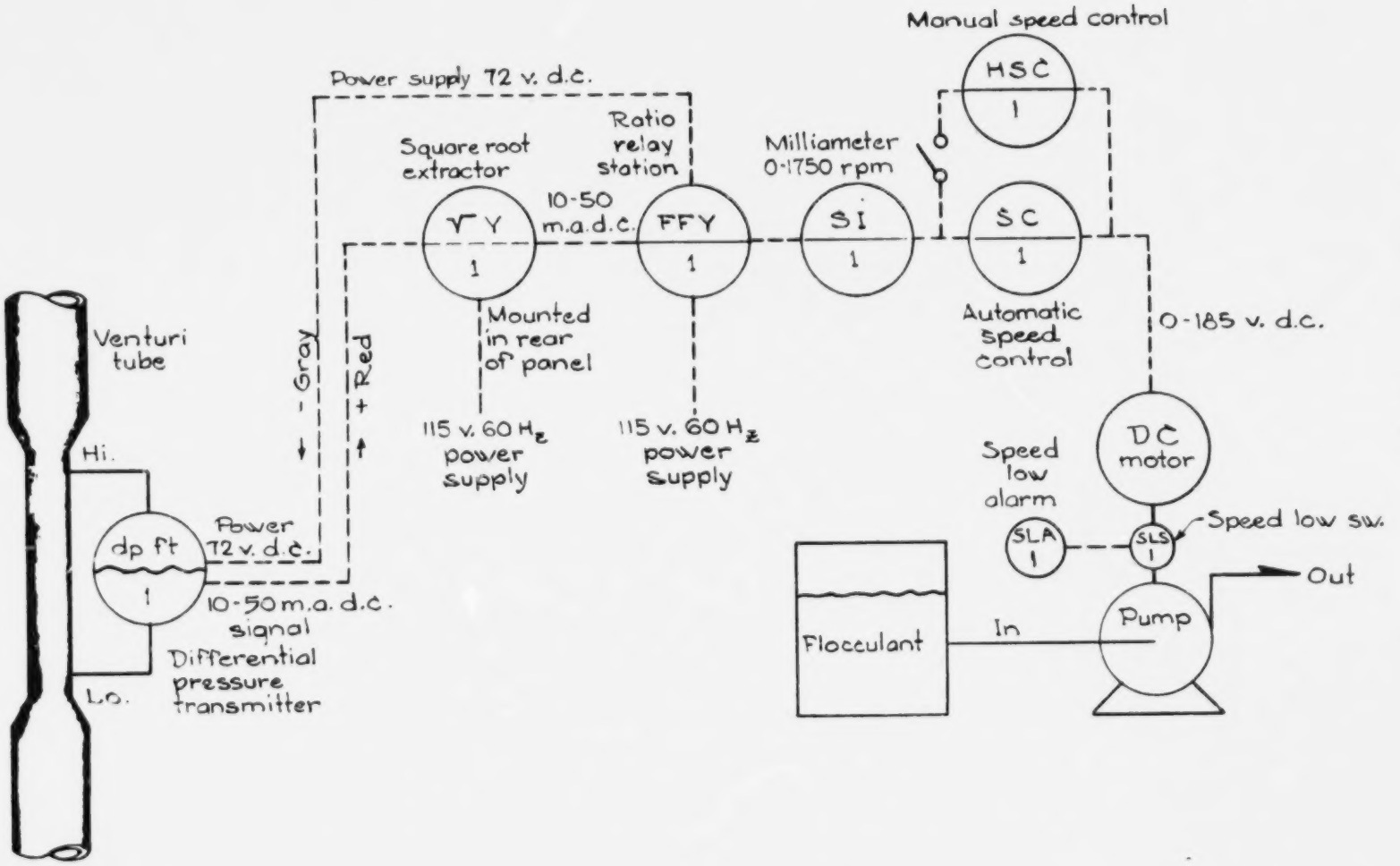


Figure 2

Electronic Polymer Programming Instrumentation

Polymer Programming Instrumentation

Item

1 Item ST-1 Foxboro Model 613 DM electronic d/p cell transmitter, medium range capsule 0-20 to 0-205 inches water or 0-7.226 psi to 0-74.066 psi.

1 Item SQC-1 Foxboro Electronic Consotrol square root converter base instrument, Model 66AR-0H Classification: General Purpose, Power input: 115v, 10% at 60 cps.

1 Item SI-1 Foxboro indicating milliameter base instrument, Model 65 PS-0HT, scale range and calibration 0-1750 rpm (uniform) legend rpm.

1 Item SRV-1 Foxboro Consotrol ratio set unit, base instrument, Model 67H G-1 Classification: general purpose, power input: 118v, 10% at 60 cps, dial range 0.30-3.0 (linear).

1 Model EH-1-A Foxboro Consotrol Shelf

1 General Electric variable speed drive. Cat. No. 104x950 AAG01. motor package (non-reversing, 1 HP, drip-proof, 1250 rpm max. speed) and 1 General Electric Power Unit, Cat. No. 6 910K1-X.

1 General Electric Operator's station, Cat. No. 104x960 AAG02.

1 General Electric Isolation Transformer, Cat No. 104x156 AA99

Note: Specifically named supplies, services, and equipment, used in this project do not constitute an endorsement by the F.W.P.C.A.

B. PROCEDURES

Proper polymer dispersal and mixing into the entire waste flow is an extremely important phase of the raw waste flocculation process. A complete inspection of the Easterly headworks indicated that good polymer dispersal would probably be achieved by addition of the polymer solution in the vicinity of the two raw sewage Venturi tubes. The old prechlorination taps into the two Venturi tubes were utilized as the first polymer addition points. Site glasses

were installed so that equal distribution of polymer to the two tubes was insured. Near the end of May (May 27), an alternate addition point was readied and put into service. The goal with this new addition point was more optimum polymer dispersal through multiple-point additions, along with more nearly equal distribution to the two tubes. This new system included four 0-20 gpm rotameters*, each rotameter controlling polymer feed to both sets of low and high pressure piezometer rings on the two Venturi tubes. This second addition point was used until October 4 when another change was made. This change was required because of clogging of the Venturi piezometer rings with polymer which adversely affected the operation of this flow measuring device. The third addition point was located at the point where the raw sewage flow splits to enter into the four preaeration tanks. Polymer addition was to four points at this flow split, and was controlled in each of four equal volumes utilizing the control rotameters described above. This third addition point was utilized until the end of the demonstration period.

After addition of the polymer into the Venturi tubes (for the first and second addition points), the raw sewage flow recombines and enters into four preaeration tanks ahead of primary sedimentation. The preaeration process includes four units of three-pass tanks, each pass 65' x 15' x 6'; designed for an average detention period of six minutes and for air agitation at the rate of 0.025 cfm. Dye studies indicated that about two minutes detention time per pass was available at average flow conditions. An additional 1.5 minutes time is available from the Venturi meters to the preaeration tanks. Thus there was a total of 7.5 minutes mixing time (at average flow conditions) between polymer addition and entry into the primary tanks feeder channel for the first and second addition points. About 6 minutes mixing was available for point number three.

*Fischer & Porter Rotasight flow rate indicators size 1-1/2 x 1-1/2 bronze with Buna N O-rings, max. 20 gpm water. No. 2235597-10A2235A.

By controlling the amount of air applied to each of the preaeration tanks, it was possible to achieve near optimum mixing conditions. Optimum conditions call for rapid polymer dispersal throughout the entire waste flow followed by slow floc-forming mixture. These conditions were created by utilizing the period from polymer addition at the Venturi tubes through the first preaeration pass, or a period of about 3.5 minutes, for rapid dispersal. The air supply to this first pass was therefore increased to provide good rapid mix conditions. Passes two and three, or about four minutes time, were utilized for slow, floc forming mix by reducing the amount of air delivered to these tanks. Air supply to the primary tank feeder channel was also reduced to an equivalent level as that in passes two and three of the preaeration tanks. In this way, extremely good mixing conditions were created.

Normal plant maintenance schedule calls for yearly drainage and inspection of the preaeration tanks. Near the end of March, such a program was begun, and therefore it was possible to study the effects of reduced mixing time on polymer performance.

Samples of raw sewage, primary effluent, and final effluent are taken automatically. The raw sewage is sampled in proportion to the flow (sample every 6 to 10 minutes) and primary and final effluent samples are taken approximately every five minutes. All samples are composited over a 24 hour period and the raw sample is refrigerated. Mixed liquor, waste activated, and return sludges are sampled manually every hour and composited for a 24 hour period. Sludge that is pumped to the Cleveland Southerly Plant is automatically sampled every seven minutes while pumping, to constitute a daily composite sample.

All laboratory analyses (BOD, COD, VSS, SS, Phosphate, Nitrogen, Total Solids and pH) are run on influent, settled sewage, and effluent samples according to accepted standard methods. Mixed liquor and waste activated sludge are analyzed for SS, VSS, and SDI. Primary sludges are analyzed for total and volatile solids content. All analyses are routine in the Easterly laboratory.

Detailed sludge pumping records, including pumping rate, force main line pressure, pump amperage required, and relative sludge concentration pumped, are recorded continuously during pumping periods on 24 hour charts. Thus excellent control parameters and accurate historical data were available to monitor the sludge pumping.

C. DATA HANDLING

Data comparison (polymer treatment vs. no polymer treatment) for a project of this scope is especially confounding. Such effects as industrial spills and power failures, along with the voluminous amount of data generated, adds to the confusion. It was decided that this comparison could best be made on an average monthly basis, and that varying periods of background data should be used according to the process being studied. This monthly comparison system seemed best because it takes into account the yearly preventative maintenance schedule and also the seasonal type treatment efficiency influences. The period of interest is that from February through November, since this corresponds to the 1968 period of polymer addition. In all cases, this was the period used for comparison. The following background data years (February through November) were used:

Average monthly BOD and SS values:	1961-67
Primary BOD and SS removal efficiencies:	1961-67
Final SS removal efficiencies:	1966-67
Final BOD removal efficiencies:	1966-67
Average monthly MLSS:	1966-67
Average monthly MLSS sludge index:	1966-67
Average monthly primary sludge concentration:	1966-67
Average monthly waste activated sludge concentration:	1966-67
Average monthly solids concentration to Southerly:	1966-67
Relative volumes of sludge pumped to Southerly:	1966-67
Relative tonnage of dry sludge to Southerly:	1966-67
Monthly blower power usage:	1966-67
D.O. in aeration tank effluent:	1966-67

It was felt that a reliable statistical average for all BOD and SS data required data from as far in history as practical. This is why the period 1961-67 was used for this background. Certain short-term comparisons (1966-67) were used for treating all final effluent data, sludge data, mixed liquor data, blower data, D.O. data, and blower power data. This short-term treatment specifically took into account the period when design flow was surpassed and the various unit processes overloaded.

Because of increases in the total population served and also increases in the average per capita water consumption, average daily raw sewage flows into the Easterly plant have risen in recent years. This trend can be seen in Figure A, where a 4% yearly increase in flow is noted from 1963 through 1967. This data was compiled from monthly averages for February through November, the period of polymer addition.

FIGURE A

AVERAGE DAILY RAW SEWAGE FLOW
(FEB. THRU NOV.)

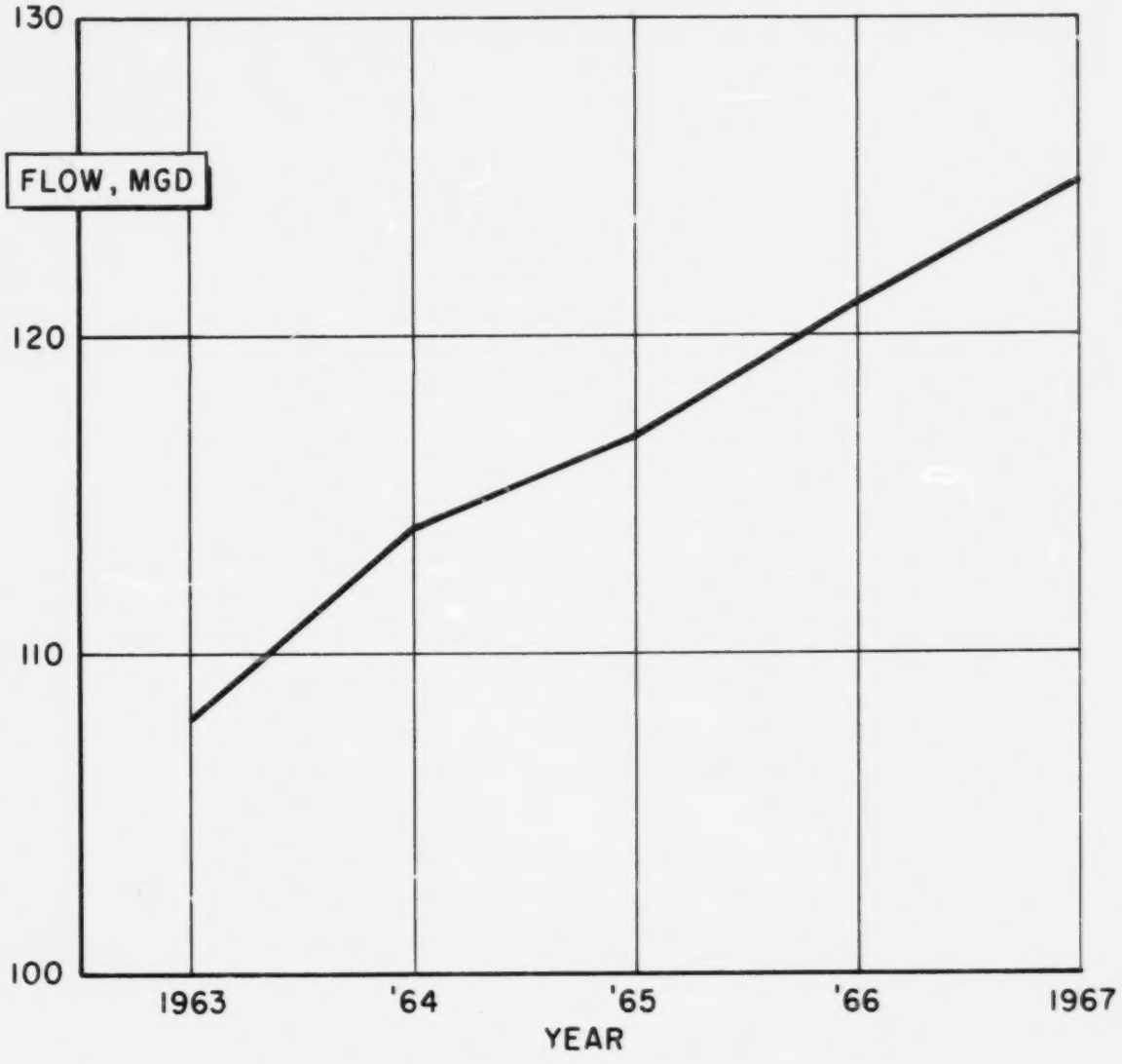


Figure B, a plot of average monthly raw sewage flows for different yearly periods, shows clearly the seasonal pattern of sewage flow such that a number of trends are established. It is also evident from this plot that the 1968 flow trends correspond to those from earlier years, indicating that 1968 could be considered an "average" year.

Several periods of very heavy rain were apparent during the 1968 demonstration period, notably during the months of April, August, and November. This effect is noted so that polymer performance and also overall plant performance during these rainy periods can be studied.

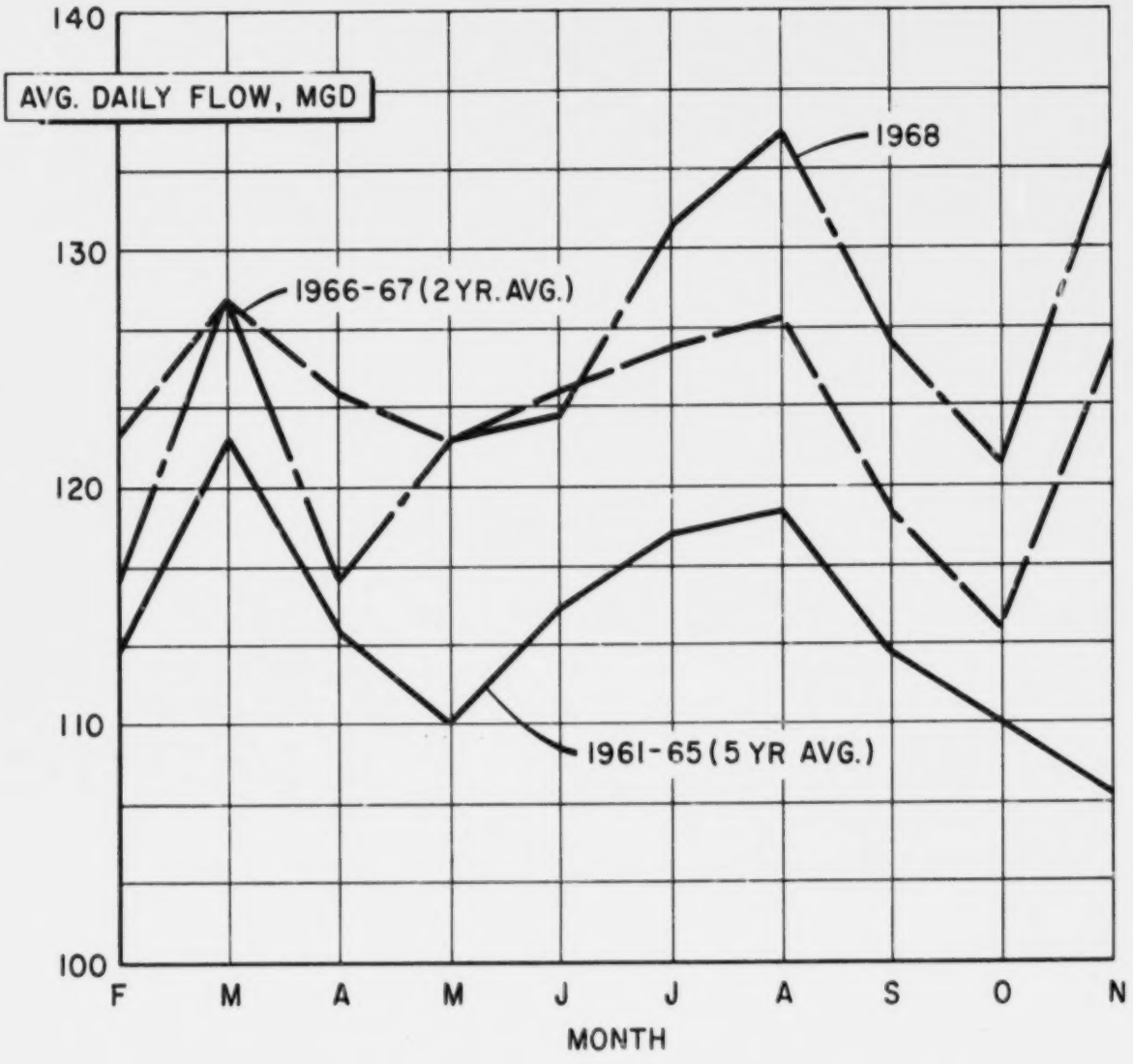
The pattern of average daily flow increases established in Figure A is extremely important. It is apparent that the Easterly average daily design hydraulic capacity of 123 MGD was exceeded in 1967 and again in 1968. This means that design sedimentation detention times and hydraulic thruputs are no longer in effect, and that the various unit processes, such as primary and final clarification, and secondary aeration, are no longer operating at design efficiencies. In addition, historical data indicates that as the raw sewage flow has increased through the years, removal efficiencies have generally decreased, both in primary sedimentation and secondary treatment.

D. PICTORIAL

These pictures were provided courtesy of Roy Simpson, Superintendent, Division Filtration Plant, Cleveland, Ohio. His expert work is greatly appreciated.

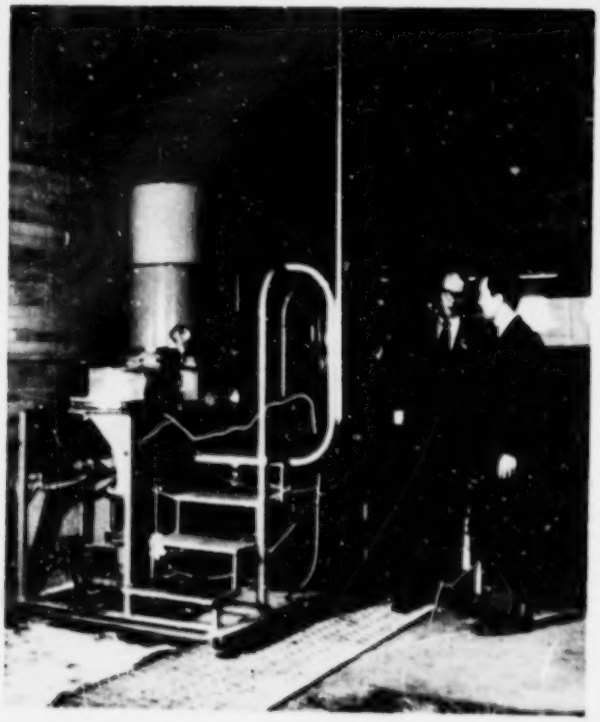
FIGURE B

AVG. MONTHLY RAW SEWAGE FLOWS (FEB THRU NOV.)

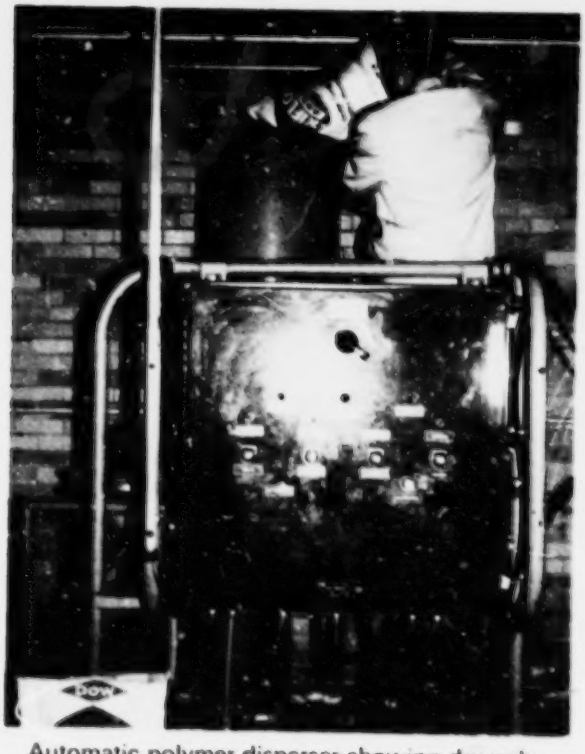


Participants in study. Left to right, Bill Constantelos, City of Cleveland; John Wirts, City of Cleveland; George Harlow, FWPCA, Cleveland Office; Ronald Schussler, Dow Chemical Co.; Walter McMichaels, FWPCA, Taft Center, Cincinnati.

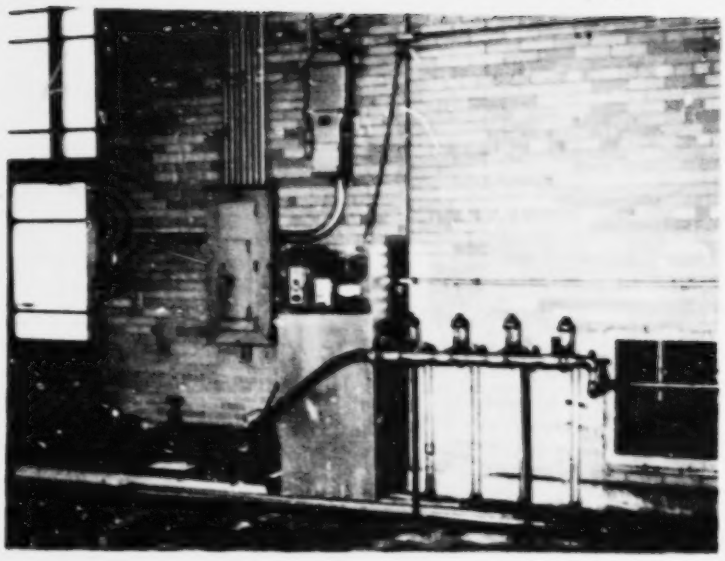
Radio-operated raw sewage automatic sampler.



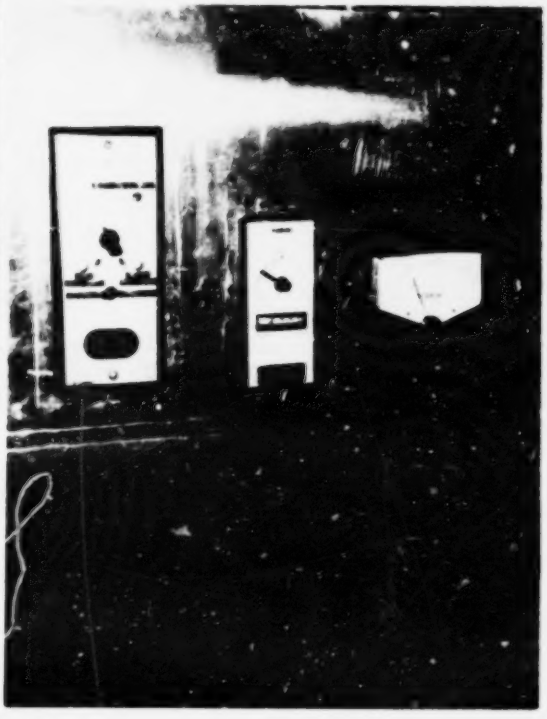
Overall view of automatic polymer dispenser.

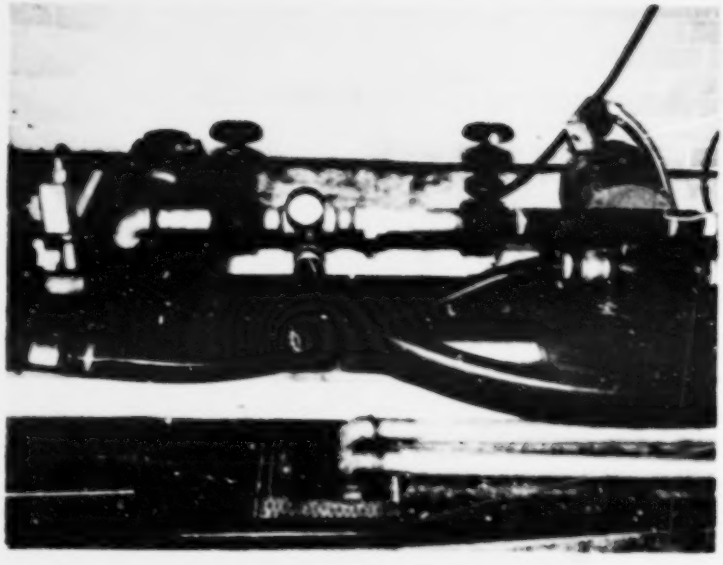


Automatic polymer disperser showing dry polymer addition into the chemical storage hopper.



Overall view of polymer programming instrumentation.

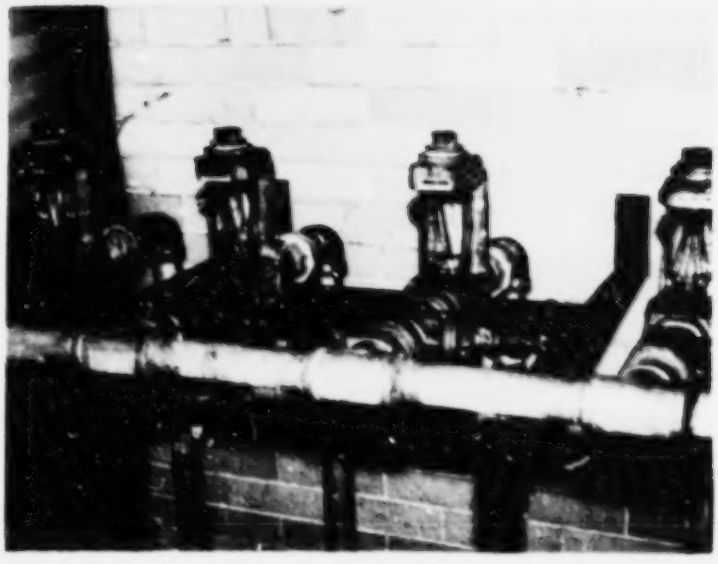




Panel mounted electronic programming instruments

Polymer metering pumps controlled by electronic instrumentation

Flow balancing rotometers to each of four polymer addition points



IV. DISCUSSION OF RESULTS

A. PRIMARY CLARIFICATION PERFORMANCE

1. Suspended Solids and BOD Removal

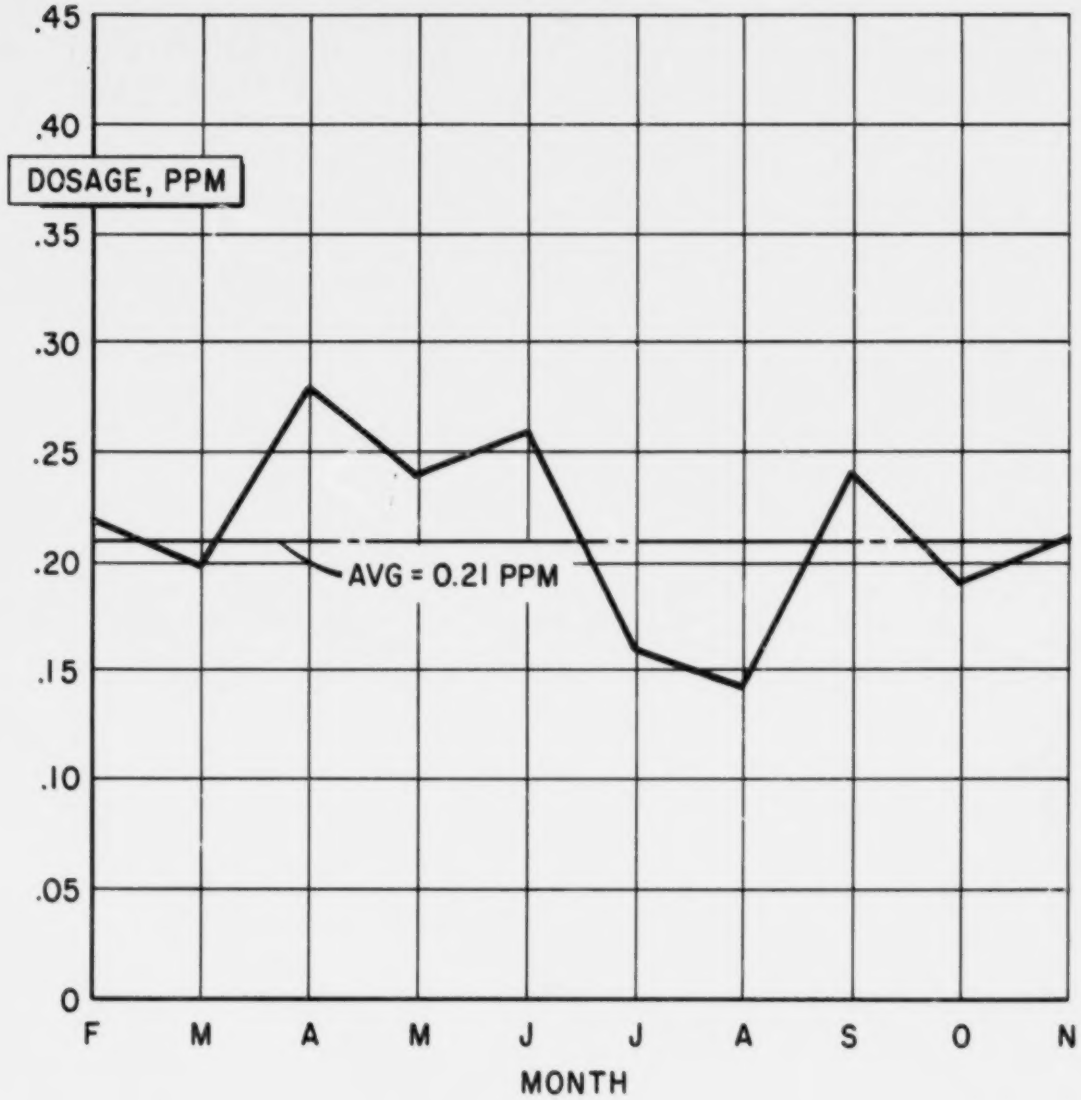
From observations made during the pre-trial period, and round-the-clock jar testing on several days, the optimum polymer dosage was determined to be 0.25 ppm, 24 hours per day. This 0.25 ppm dosage was programmed from February 12, 1968 until December 1, 1968, with the exception of the period from March 18 to March 31 where a 0.30 ppm dosage was programmed so that a comparison of polymer performance vs. dosage could be made.

Average monthly polymer dosage is shown in Figure C. Although significant monthly variance from the 0.25 ppm programmed dosage is noted, the average dosage for the ten months of polymer treatment was 0.21 ppm. The low July and August dosage can be attributed to a caking condition of the dry polymer in the feed hopper. This caking resulted in a low dry chemical feed rate, thus reducing the concentration of the polymer solution in the 1100 gallon feed tank, and thereby causing a lower-than-programmed dosage. The polymer caking condition was the direct result of using two-year old polymer that had taken on moisture in these two years. This relatively old polymer was used since it had proven activity superior to that of some of the newer lots, and thus warranted consideration.

Normal primary removal of suspended solids is reduced by out-of-service preventative maintenance. Each of the eight primary tanks was taken out of service, one at a time, during February and March. This data is included in the comparison since all such work follows a similar yearly schedule, and hence the background data periods also include this maintenance.

FIGURE C

POLYMER DOSAGE (Monthly Avg.)



Primary clarification is accomplished at the Easterly Center by eight rectangular, single pass tanks, each 115' x 50' x 15'. These tanks are designed to provide an average detention period of 60 minutes at 123 MGD rate. Sludge removal and surface skimming mechanism is of the chain driven, straight line type with three flights in each tank and a cross conveyor at the inlet end for sludge concentration. Surface loading at average flow conditions is thus in excess of 2600 gal/day/ft^2, a very high primary tank hydraulic loading. Effluent weir loadings are well beyond current design practice.

Table I presents the primary clarifier performance. Figures D and E show the monthly average suspended solids and BOD values for the background and polymer-feed periods. It is interesting to note that although average suspended solids values in the raw sewage are similar for the two periods of interest, the 1968 raw sewage BOD value is significantly lower than for the background period.

Figure F is a plot of average monthly primary SS removal efficiencies. It is seen that for the background period, an average removal of 30% was attained in the primary clarifiers, while during polymer addition an average removal of 51.6% was noted. This large increase in process efficiency (a 72% increased efficiency) reflects the flocculation activity of the polymer added. In addition, it is apparent that the polymer addition resulted in a much smoother efficiency curve than for the non-polymer period. That is, various seasonal influences such as temperature and flow are not as apparent during polymer addition. This smoothing-out effect should result in more efficient secondary process operations since a more constant load would be applied.

TABLE I

PRIMARY CLARIFICATION PERFORMANCE

	Control Period	Polymer Demonstration Period
HYDRAULIC OVERFLOW RATE, gpd/sq.ft.	2030	2170
RAW SEWAGE SUSPENDED SOLIDS, ppm	169	157
PRIMARY EFFLUENT SUSPENDED SOLIDS, ppm	117	77
RAW SUSPENDED SOLIDS REMOVED, percent	30.8	51.0
RAW SEWAGE B.O.D., ppm	151	125
PRIMARY EFFLUENT B.O.D., ppm	104	67
RAW B.O.D. REMOVED, percent	31.0	46.4
SLUDGE SOLIDS CONCENTRATION, percent	4.1	4.3
SLUDGE VOLUME PUMPED, MG/month	5.0	6.8
SLUDGE TONNAGE PUMPED, Tons/month	855	1220

FIGURE D

AVERAGE MONTHLY SUSPENDED SOLIDS VALUES

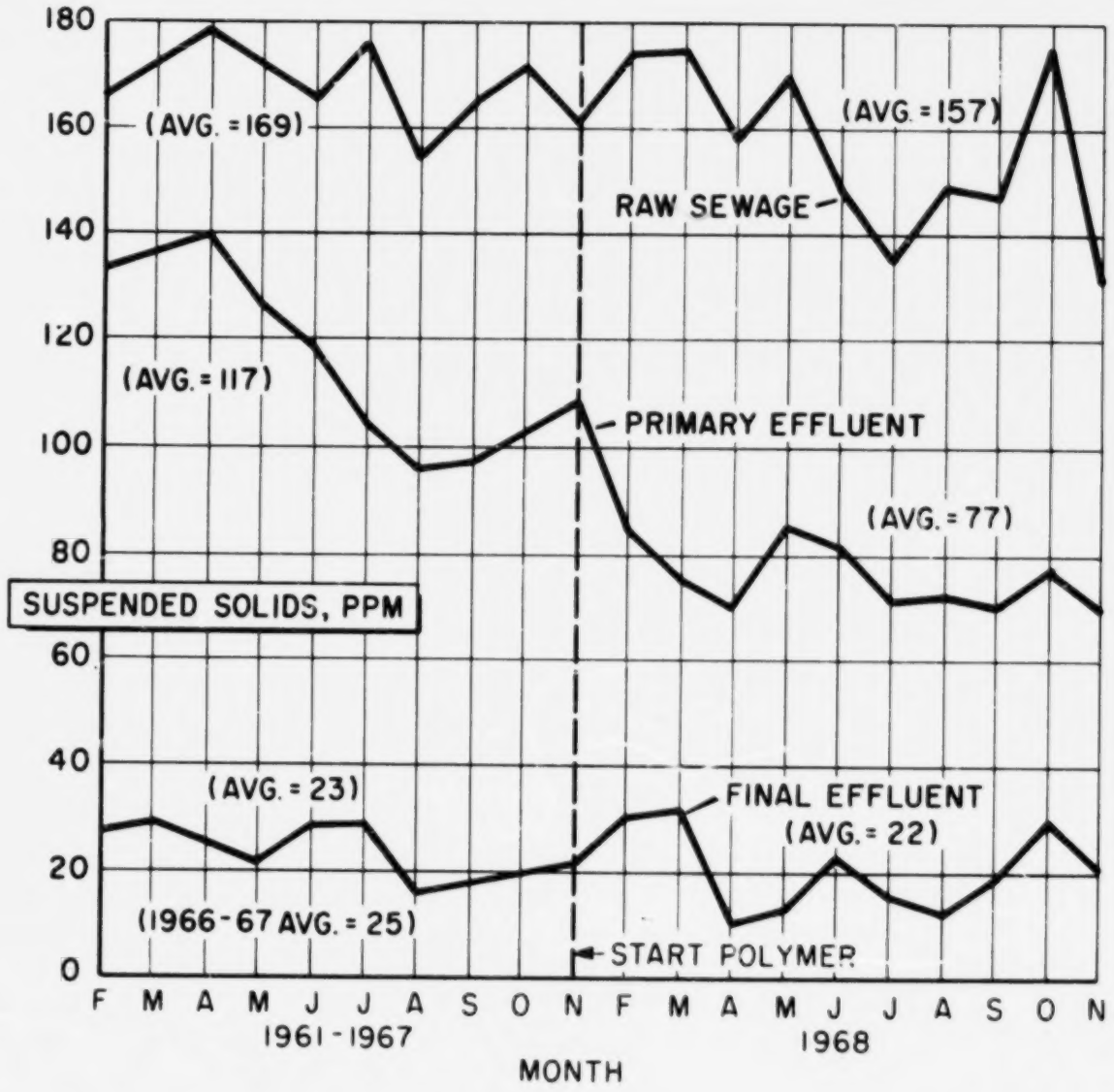


FIGURE E

AVERAGE MONTHLY BOD VALUES

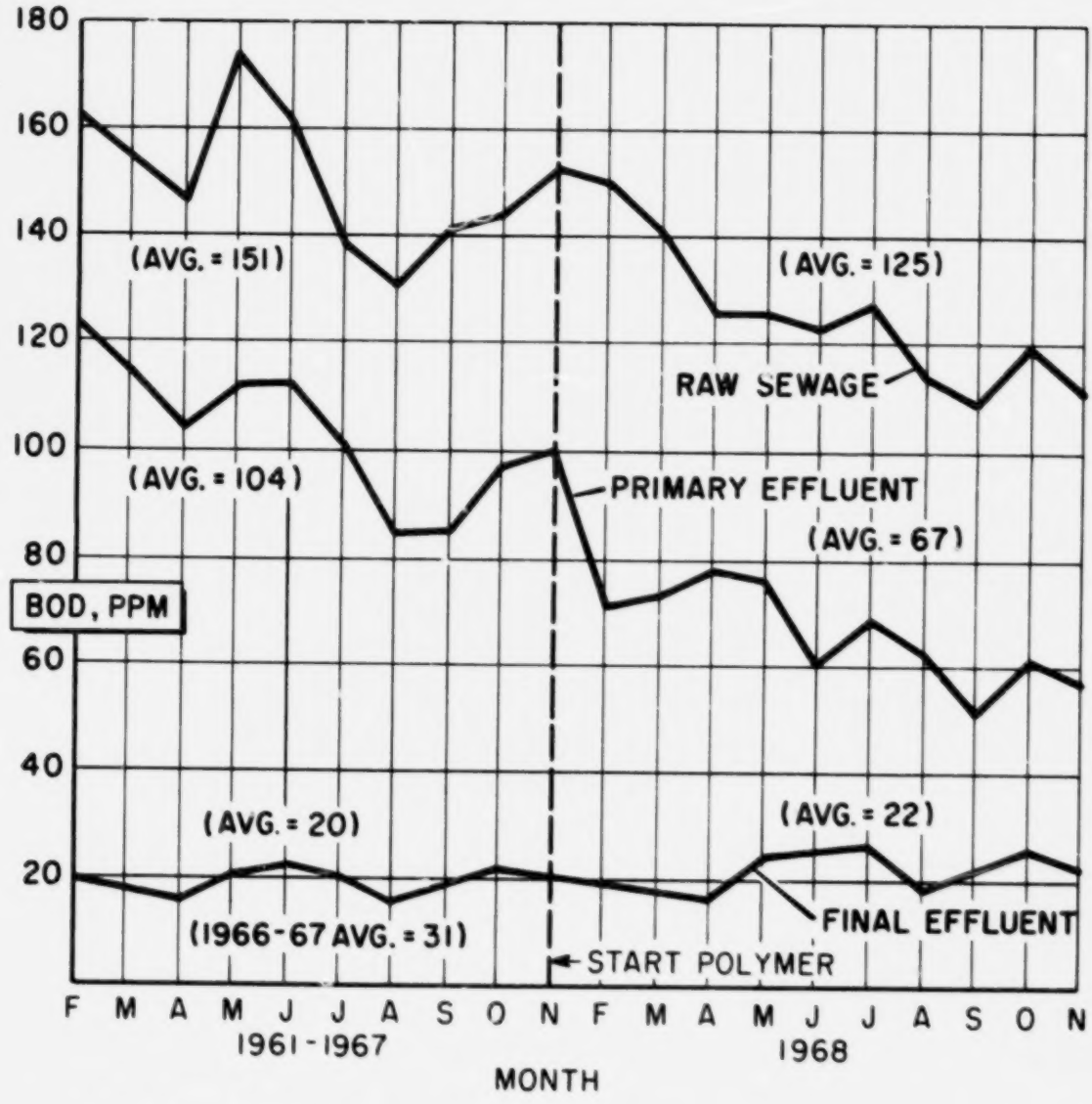


FIGURE F

AVERAGE MONTHLY PRIMARY S.S. REMOVAL EFFICIENCIES

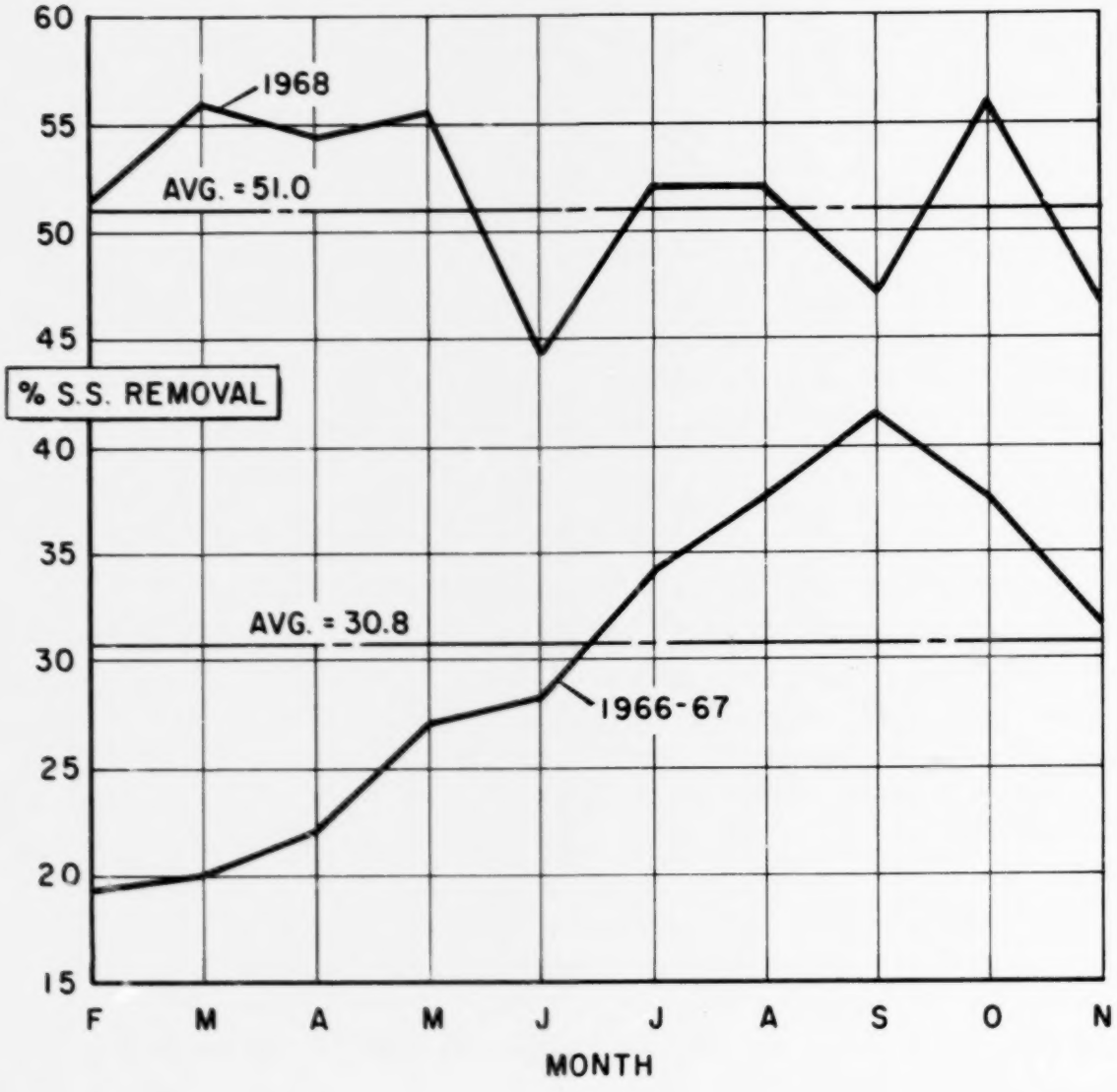


Figure G shows primary BOD removal efficiencies for the two periods of interest. During the background period, BOD removal averaged 31.6%, while during polymer treatment the average primary BOD removal was 47.3%. This is a 50% increase in efficiency due to raw waste flocculation. Again, as in the SS removal efficiency comparison, the highly variant nature of monthly removal efficiencies was reduced during polymer application.

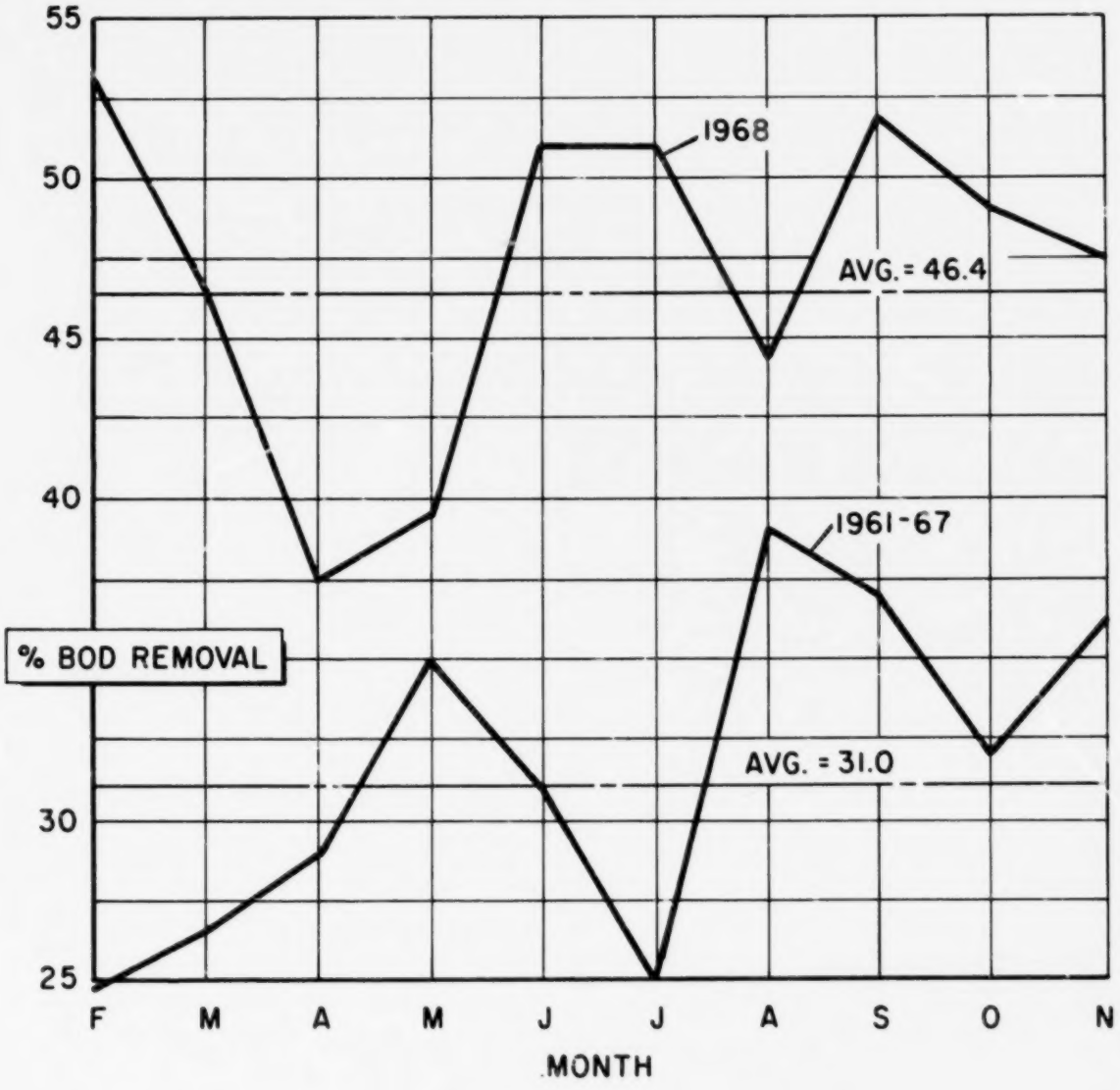
Two periods are of prime importance in the primary clarifier performance data. From March 6-11, waste activated sludge was returned to the head end of the preaeration tanks. The objectives of this return were to increase primary removals by suppling a higher ratio of solids to flocculant, and to obtain a more concentrated easier pumping primary sludge. These objectives were not realized, as primary removals averaged only 25% during this period, and solids to Southerly only 2.3%. In addition, a condition of secondary upset occurred near the end of this return period, and lasted until the end of March.

Historical records indicate a previous return of waste activated sludge to the preaeration tanks from May of 1957 until July of 1959. During this period, an average of 18.4 MG per month of waste activated was returned, resulting in an average primary suspended solids removal of only 10%. It was apparent that efficient capture of the waste activated solids did not occur in the primaries during this period, as during the polymer-waste activated return period.

From March 1-17 and March 18-31, two different polymer dosage levels were compared. These levels were, respectively, 0.17 ppm and 0.22 ppm. It was apparent that the higher dosage level resulted in higher solids capture (61%) compared to the lower dosage (50%). Laboratory jar testing work all throughout this period also confirmed that the optimum dosage was in the range of 0.25 ppm.

FIGURE G

AVERAGE MONTHLY PRIMARY BOD REMOVAL EFFICIENCIES



Also of interest is a mathematical model used to predict suspended solids removal efficiencies for primary treatment. This model, proposed by Voshel and Sak[1], relates suspended solids loadings and hydraulic loadings to suspended solids removal efficiency. It assumes that removals are directly proportional to a power function of SS content and inversely proportional to a power function of the hydraulic loading. Two equations were developed as follows: Equation I predicting non-polymer removals and Equation II predicting polymer removals:

$$R = \frac{56.75W^{0.27}}{Q^{0.22}} \quad (I) \qquad R = \frac{77.88W^{0.17}}{Q^{0.13}} \quad (II)$$

where R = SS removal efficiency, %
W = SS content of the feed, ppm
Q = hydraulic loading, gpd/sq.ft.

Using the two equations for Easterly data projection, with 1961-67 average flow and SS content being used for Equation I, the following is seen:

$$R_I = 41.2\% \qquad R_{II} = 65.7\%$$

This corresponds to actual removals of 30% during period I and 51.6% during period II which, although significantly lower than predicted, show an actual increased removal of 21.6% versus 24.5% predicted above. Other factors controlling suspended solids removal efficiencies such as hydraulic design of clarifiers, settleable solids characteristics, and degree of flocculation (natural or induced) are neglected in the above treatment. Degree of induced flocculation will be studied further in the Metals Study section of this report.

2. Phosphorus Removal

Due to the recent emphasis on nutrient removal, it was decided to monitor both total and dissolved phosphates during the demonstration period. Excellent 1966 and 1967 background phosphate data was available. Once a week composite samples of raw sewage, primary effluent, and final effluent were analyzed for total and dissolved phosphates. It was expected that during the polymer demonstration period, a fraction of additional total phosphate would be removed in primary clarification because of the increased solids capture in the primaries. It was likewise expected that the dissolved phosphate fraction would remain about constant for the control period through the polymer addition period. Following is the data developed, with all results reported as phosphorus (atomic weight 31).

	Total Phosphorus (ppm)		Dissolved Phosphorus (ppm)	
	Control	Demonstration	Control	Demonstration
Raw	6.9	7.3	3.2	3.9
Primary Eff.	5.9	5.7	3.1	3.1
Final Eff.	4.0	4.3	2.6	2.5

Based on these numbers, the following percentage reductions can be calculated for primary and secondary treatment.

	% Reduction of Total P		% Reduction of Dissolved P	
	Control	Demonstration	Control	Demonstration
Primary Treat.	14.5	22.0	3.1	20.5
Final Effluent	42.0	41.0	18.8	36.0

It is thus seen that total phosphorus removal did increase, somewhat, in primary treatment during the polymer demonstration period, but total phosphorus removal in the final effluent remained about the same. The increased removal of dissolved phosphorus during the demonstration is unexplained.

3. Nitrogen Removal

The following data was developed during the control and the polymer treatment periods.

	Free Ammonia (ppm)	
	Control	Demonstration
Raw	14	14.5
Primary Effluent	9	11
Final Effluent	8	10

It is thus seen that free ammonia reduction was similar for both periods of interest, as would be expected.

Also of interest is the nitrite and nitrate levels of the final effluent. These are as follows:

	Nitrite and Nitrate Levels (ppm)	
	Control	Demonstration
Nitrite	0.90	1.01
Nitrate	3.12	3.23

Again, very similar levels of nitrite and nitrate are apparent in both periods of interest.

4. COD Removal

Also of interest to this study was the possible reduction of Chemical Oxygen Demand in both primary treatment and through the plant. It was expected that an increase in primary COD removal would occur with the polymer treatment, and in fact this did occur as is shown in the data below.

	Chemical Oxygen Demand (ppm)			
	Control	% Reduction	Demonstration	% Reduction
Raw	351		316	
Primary Eff.	216	38	172	45
Final Eff.	79	77	69	78

It is seen that a slight increase in COD removal did occur in primary treatment with polymers, while removal through the final effluent remained unchangedd.

B. EFFECTS ON SECONDARY TREATMENT

From the preceding discussions and data it is clear that the primary effluent reaching the aeration system was much different during this project than before. Not only was the magnitude of solids and BOD reduced to the aeration tanks, but the proportion of one to the other was changed.

During the background data period (1966-67), the ratio of primary effluent SS to primary effluent BOD was 1.40 mg/mg. This figure was computed from average monthly SS and BOD values. During the polymer demonstration, the ratio of suspended solids to BOD reaching the aeration system was 1.15 mg/mg. Basically, this points out that the ratio of soluble BOD to total BOD in the primary effluent was relatively higher during the polymer addition. This decrease in milligrams of solids to milligrams of BOD will show up very readily in the production of waste activated sludge, as will be discussed below.

Table II lists some of the important parameters dealing with the aeration system. Figure H shows that the mixed liquor suspended solids were extremely erratic during the 1968 polymer program, but that the average value was close to that for the 1966-67 background period. The additional removal of BOD in the primaries with the polymer served to decrease the organic loading factor from 0.48 to 0.29 pounds BOD/pound mixed liquor volatile suspended solids under aeration. One of the most important effects realized through the secondary system was the decrease in waste activated sludge. The amount of excess activated sludge produced, based on total pounds of activated sludge wasted without corrections for solids in the primary effluent, during the background period was

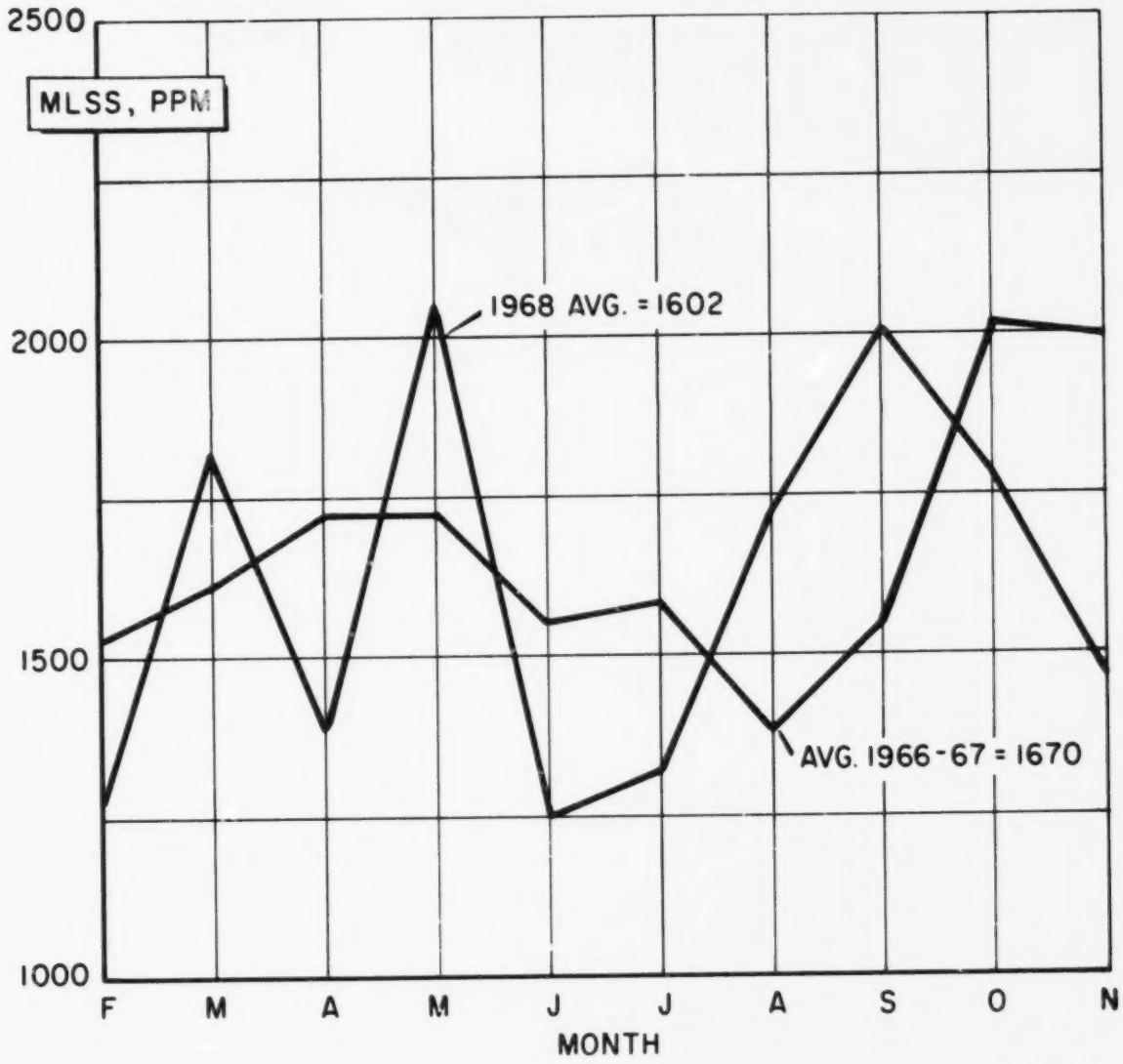
TABLE II

AERATION TANK PERFORMANCE

	Control Period	Polymer Demonstration Period
MIXED LIQUOR SUSPENDED SOLIDS, ppm	1670	1602
ORGANIC LOADING, lb/lb	0.48	0.29
DISSOLVED OXYGEN, ppm	3.2	3.8
AIR USED, cu ft/lb MLVSS	128	100
WASTE ACTIVATED SLUDGE CONCENTRATION, percent	2.4	2.0
WASTE ACTIVATED VOLUME PUMPED, MG/month	12.3	9.8
WASTE ACTIVATED TONNAGE PUMPED, Tons/month	1230	815

FIGURE H

AVERAGE MONTHLY MIXED LIQUOR SUSPENDED SOLIDS



1.64 pounds wasted per pound of BOD removed in aeration. This value comprises excess solids produced from synthesis of soluble and insoluble organics to biological mass, and inert suspended solids not captured in the primaries. During polymer treatment the amount of waste activated solids decreased to 1.15 lbs./lb. of BOD removed in aeration. It is thus apparent that the increased reduction of suspended solids in the primary effluent with polymer treatment significantly lowers the ratio of pounds activated sludge wasted per pound BOD removed in aeration. In addition, the decrease in organic loading factor reported above resulted in a decreased volume and tonnage of waste activated sludge as seen from Figures I and J. That is, the average volume of waste activated sludge produced during the 1966-67 control period was 12.3 MG/month, while during the polymer period an average volume of 9.8 MG/month was apparent, or a 20% decrease. Relative dry tonnage of waste sludges produced averaged 1230 tons/month during the control period and 815 tons/month during polymer treatment, a decrease of 34%. This decrease, then, was due to: 1) some BOD never arriving at the aeration tank which had it arrived with its high solids ratio, would have produced waste at the old rate of 1.64 lbs./lb. BOD removed; and 2) BOD which did reach aeration but produced waste solids at the new rate of 1.15 lbs./lb.

This data generated on waste activated sludge production is important enough to be the subject of an entire paper in itself. The ability to control the amount of waste is extremely valuable to both existing plants and those to be designed in the future. The data generated herein shows that the control of solids associated with the BOD entering aeration has a large influence on waste sludge. The production of waste sludge at Easterly, 1.64 and 1.15 lbs./lb. BOD removed, is admittedly very high. However, it is interesting to note that where the data is reworked to take into account the relative amounts of soluble BOD and SS actually contributing BOD, then the sludge production changes considerably. Making this

FIGURE I

RELATIVE VOLUMES OF SLUDGE PUMPED TO SOUTHERLY IN MG PER MONTH

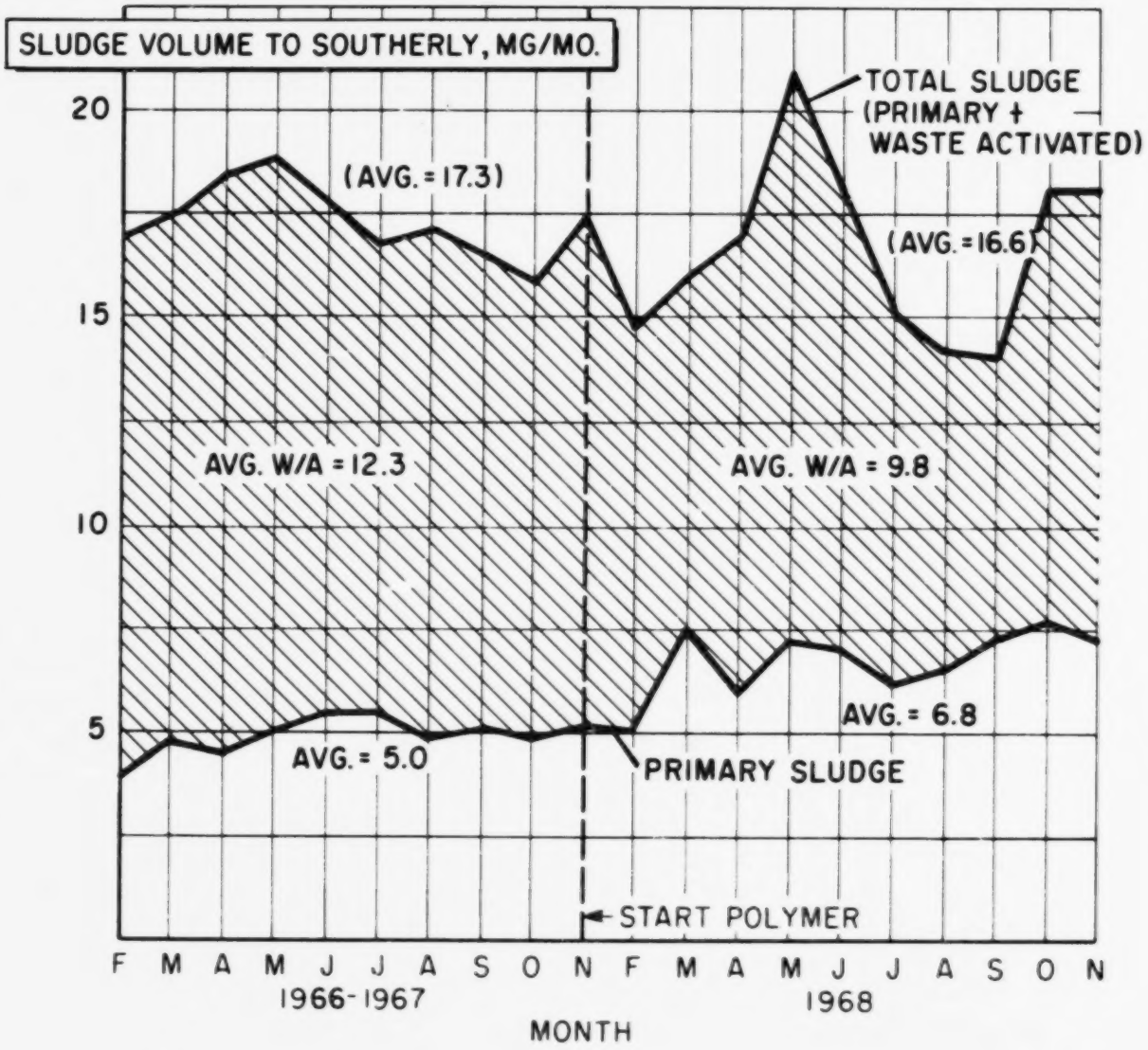
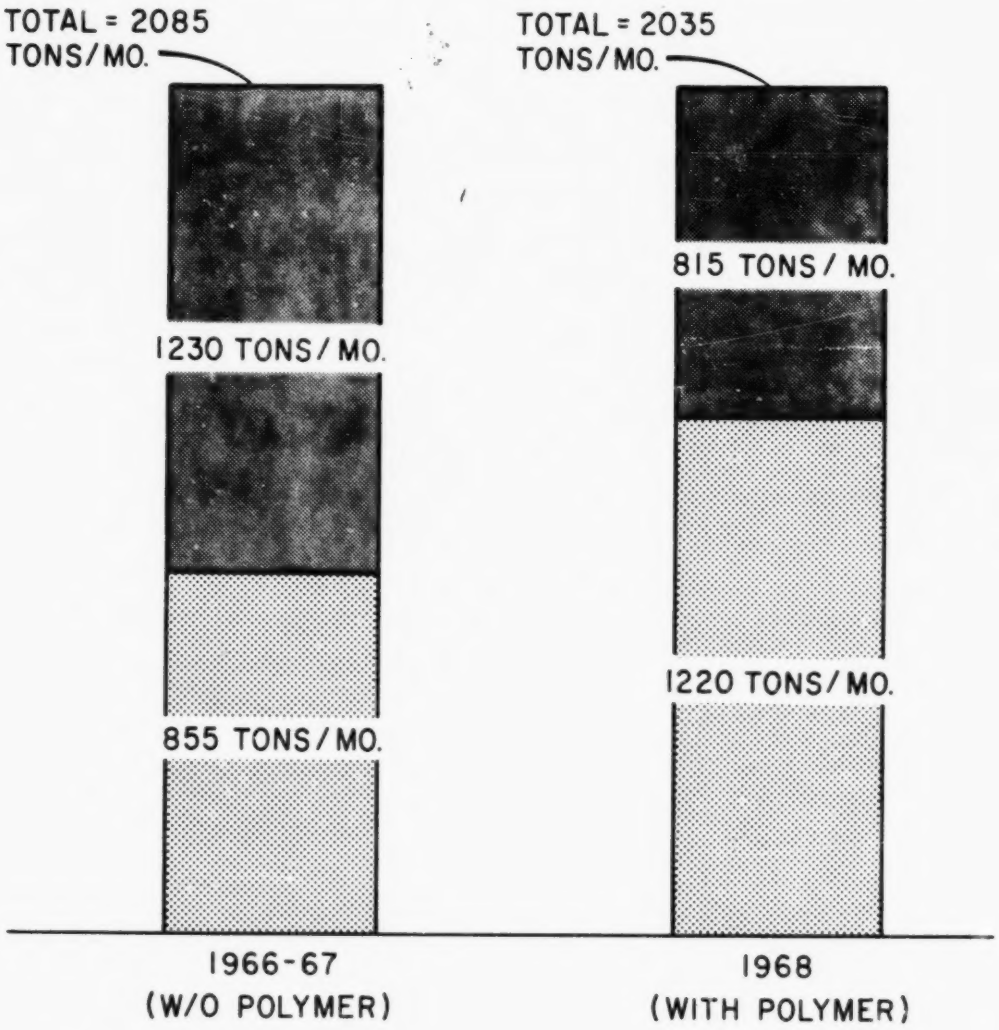


FIGURE 3

RELATIVE TONNAGE OF DRY SLUDGE SOLIDS DELIVERED TO SOUTHERLY IN TONS PER MONTH


TOTAL = 2085 TONS/MO.
TOTAL = 2035 TONS/MO.
815 TONS / MO.
1230 TONS / MO.
1220 TONS / MO.
855 TONS / MO.
1966-67 (W/O POLYMER)
1968 (WITH POLYMER)
TONS / MO. DRY SOLIDS FROM WASTE ACTIVATED
TONS / MO. DRY SOLIDS FROM PRIMARY TREATMENT

calculation on the theory that the inert solids missed in the primaries should be subtracted from the total waste sludge gives a more familiar value of about 0.69 pounds of waste sludge per pound of BOD removed. This value was nearly the same in both the control and polymer application periods.

Along with carefully watching the mixed liquor suspended solids, much concern was given to the sludge volume index. The sludge volume index is the volume in ml occupied by 1 gram of sludge, dry weight, after 30 minutes of settling. The sludge volume index generally varies from 60 to about 120, with a "bulked" sludge possessing an index of 200 or more. Figure K compares the sludge volume index for the two periods of interest. It was not known how changing the BOD feed to aeration to a predominantly soluble form would affect the characteristics of the sludge. With the start of the experiment, the value of the SVI began increasing. However, with time, the SVI stabilized and reached acceptable levels. It is important to emphasize that a stable, well-settling biological floc was produced in 5.0 hours average aeration even though the BOD to aeration was predominantly soluble with raw sewage flocculation.

Another improvement obtained in the aeration system was an increase in the mixed liquor dissolved oxygen. Figure L illustrates the monthly variations in this DO level. Because higher DO levels were noted early in the polymer addition period, it was possible to significantly reduce the quantities of air (oxygen) supplied to the aeration system. For the background period a figure of 129 cu. ft. of air per pound mixed liquor volatile suspended solids was required. For the polymer period 100 cu. ft. of air per pound MLVSS was required, a reduction of 22%. This is a net reduction since the poundage of MLVSS was essentially constant during both the control and polymer periods (1.12×10^6 lbs./day vs. 1.14×10^6 lbs./day).

FIGURE K

SLUDGE VOLUME INDEX OF MIXED LIQUOR SOLIDS

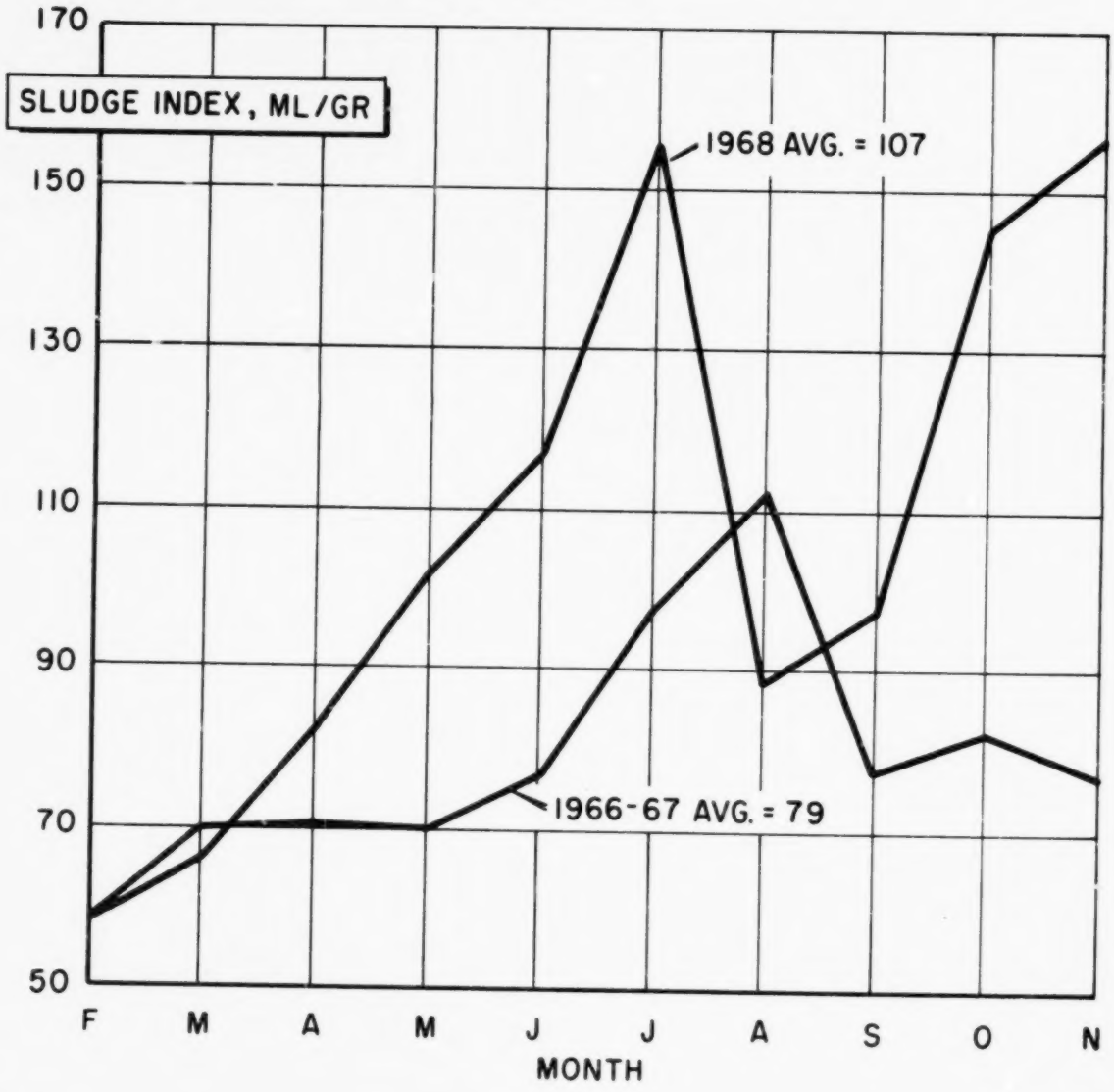
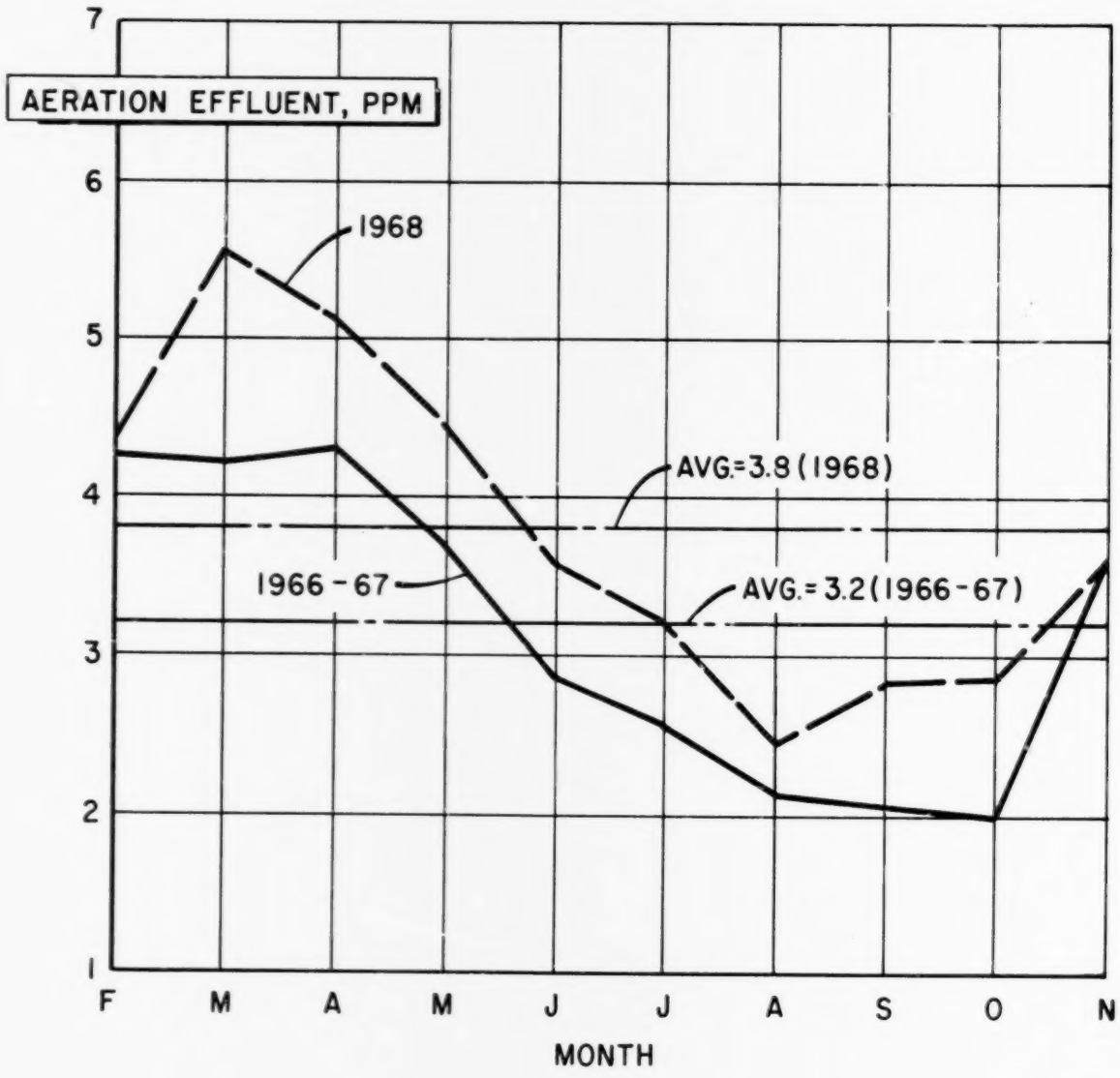


FIGURE L

D.O. IN AERATION TANK EFFLUENT



C. EFFECTS ON FINAL EFFLUENT

The results in the final plant effluent complete the story of the hydraulic flow stream. Table III lists some of the important parameters associated with the final effluent. It must be emphasized that the normal plant operating conditions produce an acceptable final effluent. If the final effluent suspended solids and BOD were initially very high, the degree of improvement of these parameters in the final effluent would be more impressive. Data handling for the final effluent quality is made especially difficult by such unavoidable occurrences as power failures, secondary upset conditions, and industrial spills.

For the case of power failures, even small duration total failures prove damaging to the entire population of biological organisms in the aeration tanks. Before the damage is restored and normal operation attained, hours and days are required. Partial failures that allow some oxygen transfer are not as damaging and hence can be tolerated. Such total failures were common in June and October of 1968, as reported in Section F. These failures severely affected data quality in certain periods of these two months, as shown in Figures M and N.

A secondary upset condition from March 9 until near the end of March was apparent. This upset was caused by the March 6-11 waste activated return to the primary tanks. Very high MLSS concentrations were noted during this period of upset, and although BOD removals were high, biological flocculation was impaired (biological mass still in inefficient log growth phase) as seen in Figure M.

A very severe railroad diesel oil spill occurred on October 18. A minimal estimate of 52,500 gallons of oil was made by the Easterly staff. More than 12 inches of oil was noted on the tops of preaeration and primary tanks. Plant performance was severely affected from October 18 to early November. The activated sludge

TABLE III

FINAL EFFLUENT PERFORMANCE

	Control Period	Polymer Demonstration Period
FINAL EFFLUENT SUSPENDED SOLIDS, ppm	25	17
PLANT REMOVAL SUSPENDED SOLIDS, percent	85.3	89.2
SUSPENDED SOLIDS IN FINAL EFFLUENT, #/day	26,000	17,700
FINAL EFFLUENT B.O.D., ppm	31	21
PLANT REMOVAL B.O.D., percent	79.1	83.4
B.O.D. IN FINAL EFFLUENT, #/day	32,000	21,900

FIGURE M

FINAL S.S. REMOVAL EFFICIENCIES

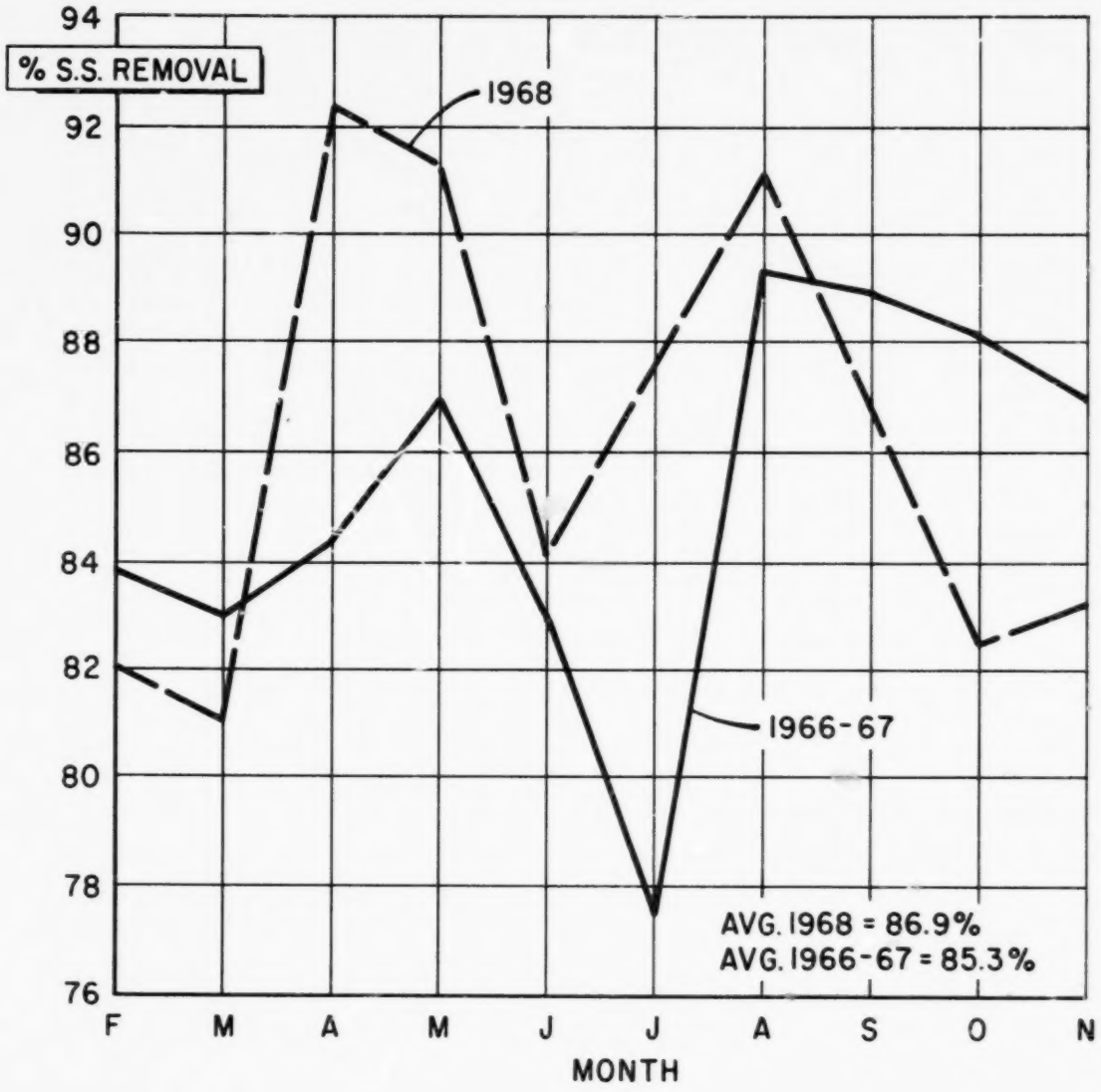
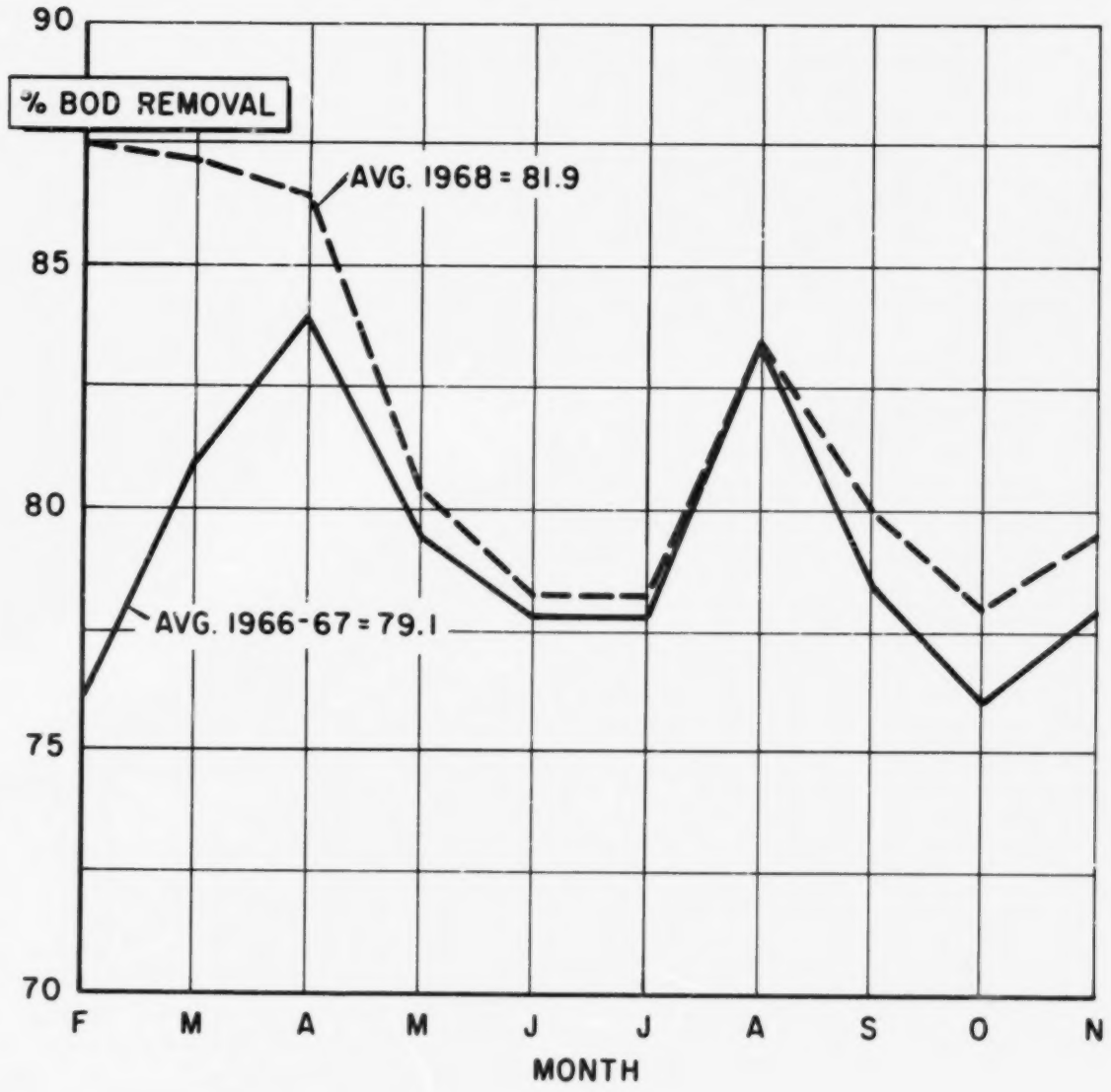


FIGURE N

FINAL BOD REMOVAL EFFICIENCY



microorganisms approached a bulking condition near the end of October, thus severely affecting aeration system performance. The oil seemed to act as a solvent for grease, and skimming became impossible.

Neglecting all data affected by these occurrences (power failures, secondary upsets, and oil spills), a more realistic average final effluent of 21 ppm BOD and 17 ppm SS is obtained. These values are reported in Table III, along with the more realistic 83.4% BOD removal efficiency and 89.2% SS removal efficiency. Figures M & N and D & E present the final effluent data without modification for the above three occurrences so that a comparison can be made.

Figures O and P show graphically the degree to which the load was reduced to the activated sludge system. An increased removal of 30,000 pounds per day of SS and 13,000 pounds per day of BOD was obtained in primary treatment during polymer application. The average final effluent BOD and SS loadings reflect this polymer aided primary removal increase. Figures O and P were prepared using the values reported in Table III. Probably the most important benefit obtained in the final effluent is the pounds per day SS and BOD contained in the final effluent. Table III and Figures O and P reveal a final effluent SS loading of 26,000 lbs./day during the control period vs. a loading of 17,700 lbs./day during polymer treatment. Similarly, BOD loading during control was 32,000 lbs./day, while during polymer treatment 21,900 lbs./day. Thus a reduction in SS loading to Lake Erie of 31% and a BOD loading reduction of 32% were attained during polymer treatment.

FIGURE O

RELATIVE SUSPENDED SOLIDS REMOVAL EFFICIENCIES

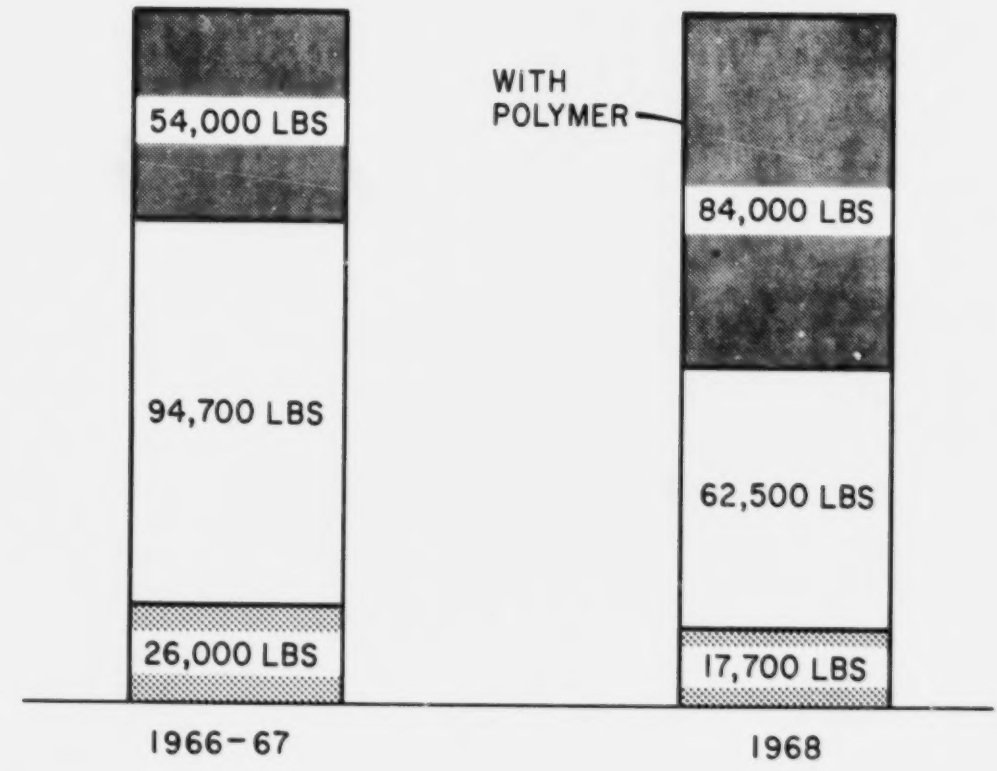
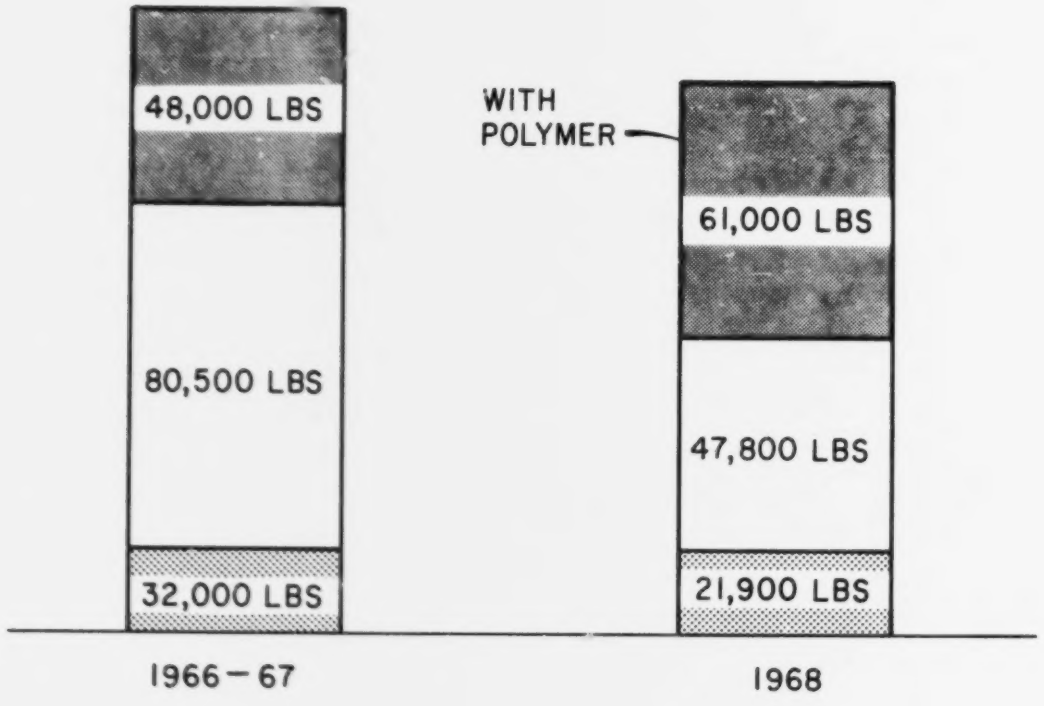


FIGURE P

RELATIVE B.O.D. REMOVAL EFFICIENCIES



D. SLUDGE PUMPABILITY

A very important segment of this demonstration was the sludge pumpability studies. Sludge disposal at the Easterly Center is by pumpage of skimmings, and raw and excess activated sludges through a 12 inch diameter 13 mile force main to the Cleveland Southerly plant. Disposal at Southerly includes digestion, elutriation, vacuum filtration, and incineration. Although this force main profile has many peaks and valleys conforming with the ground surface, it is on a generally ascending grade from the pumps at Easterly to a wide ridge between the two plants, and then, on a relatively sharp descending grade from the south side of this ridge to the Southerly plant. The controlling high point of this line (from the standpoint of pumping) is 12.5 miles from the Easterly pump room, at an elevation 161 feet above the pumps. At its terminal point at Southerly, the line is 41 feet higher than the Easterly pumps. Sludge pump configuration at Easterly is of a three-stage arrangement, designed for a sludge flow of 700 gpm and a head of 525 feet. Force main volume is about 420,000 gallons.

Force main design was on the basis of 700 gpm against a total head of 340 feet, including the 161 foot static head and 179 feet of friction loss allowance. This friction allowance was based on a Hazen and Williams coefficient "C" of 90 for water. It was designed to transfer raw primary and excess activated sludge having a moisture content of 97 percent or more, at a maximum rate of one million gallons daily.

The sludge pumps and force main were placed in service in 1939. Friction head losses in the force main have been proven by operation to be much greater than the 179 foot allowance provided in the design. The very high friction losses have been due to poor pumpability characteristics of the raw sludge, and also to build-up of grease which tends to choke the line. Line cleaning

became necessary in 1940 because of clogging by the accumulation of grit and grease. A hydraulic pressure driven scraper is used routinely for line cleaning. Frequency of line cleaning has gradually increased, and since 1963 has been at three week intervals.

The historical procedure for this three week line cleaning has included first flushing the line with degritted raw sewage for a period of 36 hours. This sewage is pumped through the line until a flushing rate of 1.2 MGD can be maintained with the pumping head below 160 psi (370 feet). This precaution has been followed to help avoid blockage of the pipe cleaner. After the flushing period, the scraper is inserted into the line, with average scraper travel time from Easterly to Southerly about 9-1/2 hours. The force main is thus out of service for sludge transfer from two to three days each time it is flushed and cleaned.

A comparison of average annual values for pump delivery rate, pump discharge pressure, and solids concentration of the sludge pumped shows that there has been a loss in average pump delivery rate (to about 0.6 MGD rate), and also in average solids concentration of the sludge pumped (to about 2.7%) over the past two years. The average annual pump discharge pressure did not increase greatly, but it is reasonable to assume that this was held down only by sacrificing pumping rate and solids concentration pumped.

Previous experience with raw waste flocculation at the Grand Rapids, Michigan, sewage plant indicated that the primary sludge obtained during polymer treatment of the raw sewage was less resistant to pumping. Sludge viscosities were shown to drop, along with a drop in sludge pump discharge pressure. It was felt that these small-scale benefits would possibly compound themselves over the long Easterly force main, producing a "more pumpable" sludge.

It is apparent that sludge pumpability is a function of the following variables: line pressure, sludge concentration, rate of pumpage, and viscosity. Accurate measurements of the first three variables are recorded daily at the Easterly Center, so that the one remaining variable, viscosity, needed to be measured. Historical practice has been to pump the two sludges separately (primary and waste activated) due to sump limitations.

A theoretical analysis of the flow of sludge through the Easterly force main, as per Caldwell and Babbitt[2], indicated a critical velocity of about 6.5 ft./sec. for primary sludge and 4.5 ft./sec. for waste activated sludge. That is, below the critical velocity plastic flow exists, and above this velocity turbulent flow predominates. A pumping rate of 1.0 MGD corresponds to a line velocity of 2.4 ft./sec., so that sludge flow in the force main is always plastic type flow. The Stormer viscometer with a modified cup was used to determine the relative viscosities required to obtain the critical velocity measurements.

To calculate this critical velocity, it was necessary to determine constants for each of the two sludges. These constants, the yield value and the coefficient of rigidity, have been shown to be independent of the characteristics of the measuring apparatus for plastic flow[3], and hence depend only on the nature of the sludge.

Since it was established that sludge flow was in the plastic region, a simplified equation[2] to determine the sludge viscosities could be used. Following is a compilation of sludge viscosities in cps for the control and polymer addition periods:

Polymer		No Polymer	
Sludge	Viscosity (cps)	Sludge	Viscosity (cps)
12.5% raw	3,020	10.0% raw	2,853
5.3% raw	690	4.9% raw	920
7.2% raw	935	7.5% raw	1,365
3.0% raw	470	3.6% raw	685
2.0% w/a	125	2.0% w/a	107
2.5% w/a	211	2.5% w/a	230
2:1 blend of 2% w/a to 6% raw	208	2:1 blend of 2% w/a to 6% raw	215

The data reported above indicates that with polymer treatment, raw sludge viscosities are generally lower than during non-polymer treatment. The data reported for the blend of raw and waste activated sludges indicate that the rheological behavior of this blend is very similar to that of straight waste activated sludge.

Based on the rheological behavior of this blend, it was decided to mix raw and waste activated sludges in the sump, so that about a 2:1 mixture (w/a to raw) could be pumped to Southerly. This mixture was made possible by utilizing the plastic return line (intended for w/a recycle to the primary tanks) to drop w/a sludge into the top of the sump. Raw sludge flow to the sump is by gravity, so that the sump level must be carefully controlled in order to maintain a sufficient raw sludge flow.

This important operational change of blending the two sludges for pumpage to Southerly took place in mid-April. Although separate phases were pumped during the first two months of the demonstration, it was found that no significant ease of pumpability of the raw phase could be measured, even though the viscosity was generally lower with polymer treatment.

The blending of raw and w/a sludges for pumpage to Southerly allowed an average pumping rate of greater than 1 MGD to be maintained. This higher rate, without a dangerously high line pressure, resulted in fewer line pluggings, and meant that sludge pumpage consumed less total time per day. One drawback, however, was the fact that at this high rate of total pumpage, a much higher than normal w/a withdrawal rate from the concentration tanks was required to insure the 2:1 mixture of w/a to raw sludge, since raw sludge is withdrawn at a constant rate from the primaries. This necessarily high rate of w/a withdrawl tended to produce a less concentrated w/a sludge, as shown in Figure Q. Thus the total concentration of solids delivered to Southerly was reduced by this lower w/a figure, but the higher primary solids concentration and greater ratio of primary to w/a sludges tended to increase the overall concentration of sludge delivered to Southerly during the demonstration, as shown in Figure R.

As a direct result of this sludge blending, in July the force main cleaning schedule was changed to a cleaning every four weeks. Up until July, this cleaning was performed once every three weeks. In addition, the practice of flushing the force main immediately before insertion of the hydraulic scraper was reduced from 36 hours of raw sewage flushing to only 16 hours of flushing. This reduction in flush time was initiated in June.

It is thus apparent that the interval between line cleanings was extended, along with a significant decrease in the total time required for this line cleaning. Since no sludge pumpage can take place during cleanings, a general deterioration of the final effluent to Lake Erie is noted due to an increased overflow of concentrated waste activated solids that are necessarily stored in the concentration tanks during line cleaning. An estimated two tons of secondary solids were thereby kept from the Lake.

FIGURE Q

AVERAGE MONTHLY PRIMARY SLUDGE & WASTE ACTIVATED SLUDGE CONCENTRATIONS

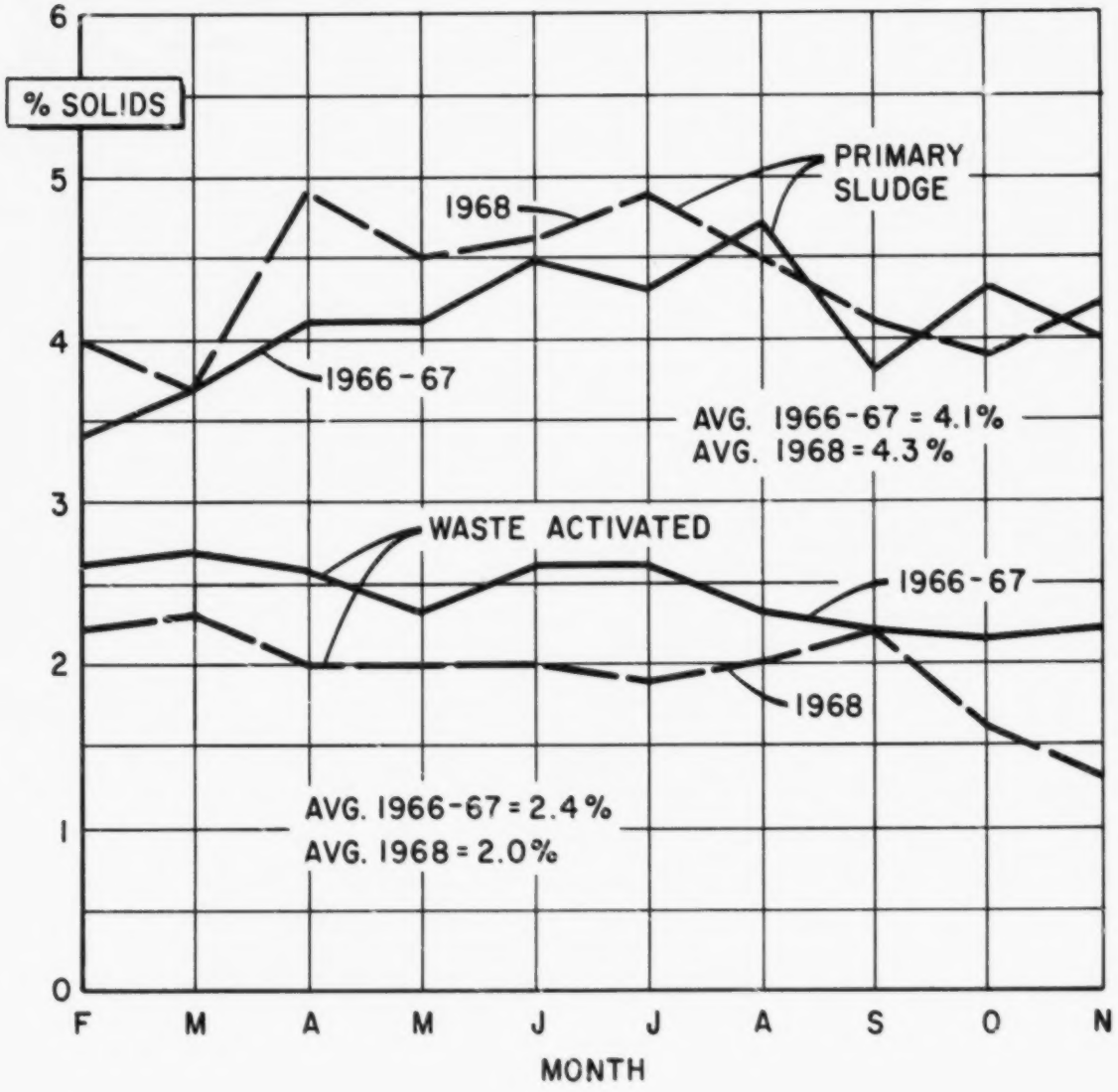
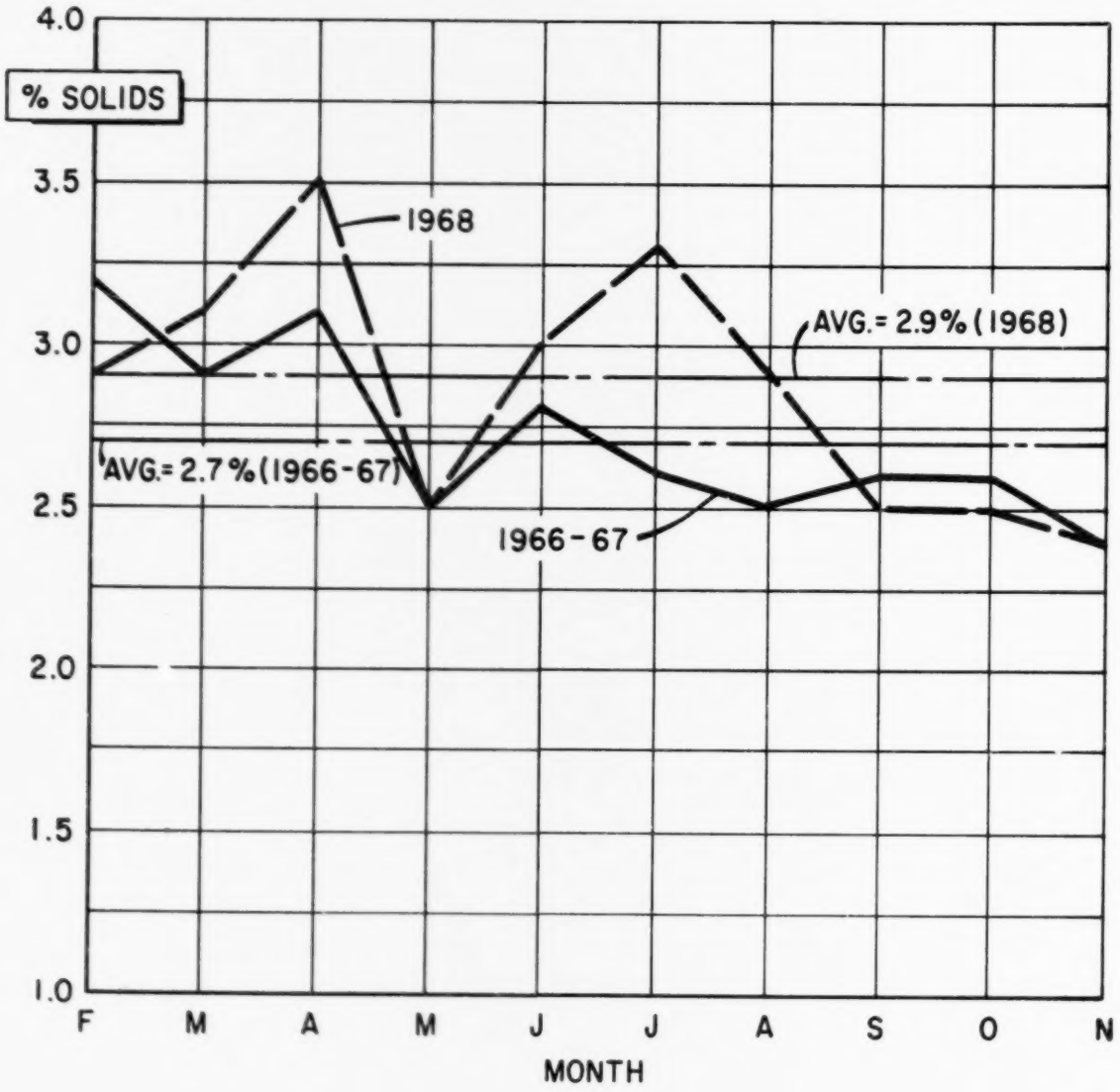


FIGURE R

AVERAGE MONTHLY % SOLIDS DELIVERED TO SOUTHERLY
(COMBINATION OF PRIMARY, WASTE ACTIVATED, & SKIMMINGS)



E. METALS STUDY

A special 14 day metals study was run for two different periods during June and July. The objective of this study was to determine the effect of raw sewage metal concentration on polymer activity. Historical data shows that the metals of consequence in the Easterly raw sewage are the following:

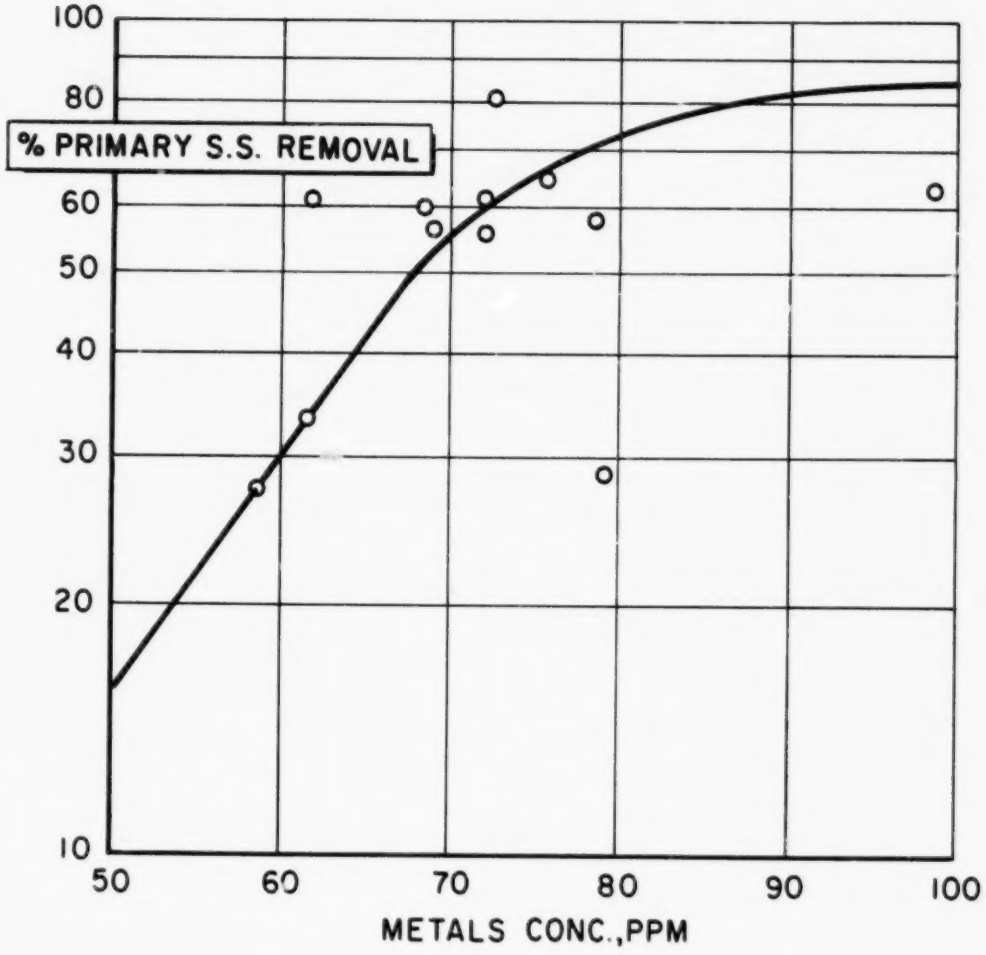
Aluminum	Manganese
Calcium	Nickel
Chromium	Lead
Copper	Silicon
Iron	Zinc
Magnesium	

It was decided that these eleven metals should be analyzed for in samples of raw sewage unfiltered, raw sewage filtered, and primary effluent filtered. Twenty-four hour composites were used. All analytical work was performed by The Dow Chemical Company Analytical Laboratories, utilizing the Emission Spectroscopy method. Polymer activity was measured by percent primary suspended solids removal for the 14 days of interest.

Various statistical methods were tried to correlate polymer activity with single metals concentrations and multiple metals concentrations. These methods were also used in an effort to correlate activity with raw sewage soluble and total metals, and also metals uptake as measured by the difference between raw sewage soluble and primary effluent soluble metals. It was found that correlation of total soluble metals as measured by the arithmetic sum of calcium, magnesium, and iron concentrations in the raw sewage, vs. primary SS removal efficiency offered the best statistical data fit. Such a plot is shown in Figure S, with the individual data reported

FIGURE S

SOLUBLE METALS CONC. IN RAW WASTE VS POLYMER ACTIVITY



below. It is important to note that individual daily polymer dosage figures for the days of interest are in the range of 0.21-0.25 ppm for all days except July 11, when the dosage was 0.12 ppm due to mechanical problems with the polymer disperser. July 11 is the data point with the greatest deviation on Figure S.

Date	% REM	Ca (ppm)	Fe (ppm)	Mg (ppm)	Total (ppm)
6-17	80.4	58.0	4.4	10.0	72.4
6-18	59.5	54.0	2.2	12.0	68.2
6-19	64.6	60.0	2.6	13.0	75.6
6-20	56.6	56.0	0.3	12.6	68.9
6-23	62.5	84.0	0.2	14.5	98.7
6-24	33.3	50.0	0.5	11.0	61.5
6-26	27.1	48.0	0.4	10.1	58.5
6-27	57.3	64.0	0.4	14.0	78.4
7-4	57.1	66.0	0.2	12.5	78.7
7-8	60.7	52.0	0.5	9.3	61.8
7-9	61.2	62.0	0.3	9.8	72.1
7-10	55.6	62.0	0.2	10.0	72.2
7-11	28.8	68.0	0.2	11.0	79.2

Figure S shows that as the total soluble metals (as measured by Ca, Mg, Fe) concentration in the raw waste increases, polymer activity also increases, with the practical maximum removal efficiency being in the range of 85%. It is entirely possible that as the metal concentration increases, the efficiency of the suspended sewage particle-metal-polymer bonding also increases, until a practical maximum efficiency is reached. It is felt that such a relationship as indicated herein could be extended to other waste streams, but that the individual values would be relatively affected (either increasing or decreasing) by such factors as suspended solids concentration in the raw sewage, possible

dispersants present, and the hydraulic characteristics of the primary clarifiers. Correlation of the soluble metals to suspended solids ratio vs. activity proved also to be unsuccessful.

Figure T, a plot of raw sewage iron content for the polymer demonstration period, tends to follow the same general trend as the primary SS removal efficiencies as plotted in Figure F. This seems to be in support of the conclusions discussed above.

F. BLOWER BUILDING POWER FAILURES - 1968

Total power failure May 26 from 11:00 a.m.-11:20 a.m. All units in at 12:40 p.m.

Total power failure June 19 from 8:50 a.m. - 9:45 a.m. Damage heavy to aeration system. Second failure June 30 from 9:37 a.m.-9:55 a.m. Trouble with blowers - estimate on time blowers on line after power restored 2.0 hours.

Total power failure October 3 from 3:40 p.m. - 4:05 p.m. Reduced to one blower October 4 at 6:30 a.m.

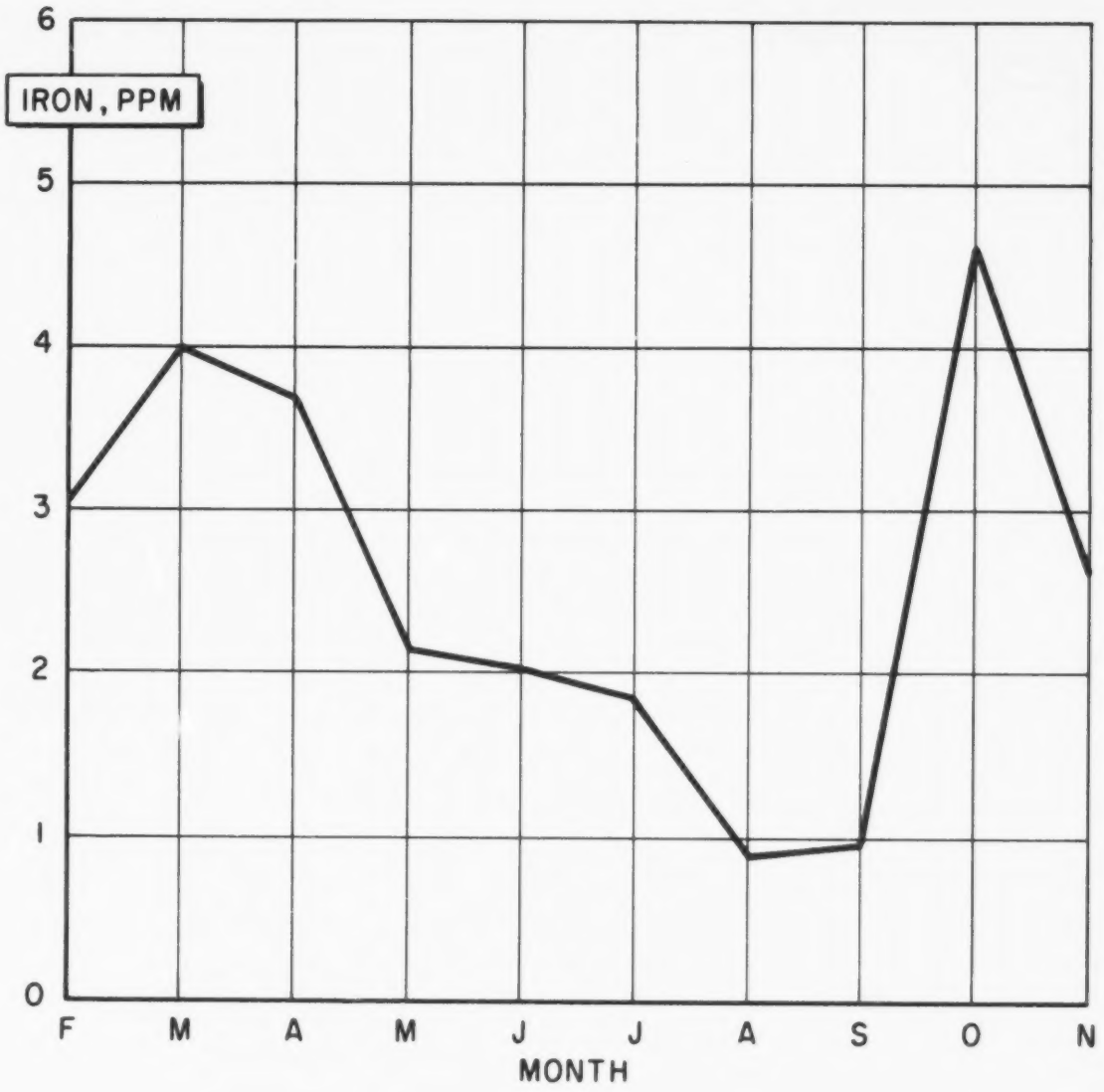
Tube failure October 21. At Muny's request one large blower on line.

Blower Operation October 21 through October 30

	No. 1 Blower	No. 2 Blower	No. 3 Blower
21	0 hrs.	24 hrs.	3 hrs.
22	17 hrs.	24 hrs.	
23	12 hrs.	24 hrs.	
24	19 hrs.	24 hrs.	
25	10 hrs.	24 hrs.	
26	24 hrs.	24 hrs.	
27	24 hrs.	24 hrs.	
28	17 hrs.	24 hrs.	
29	18 hrs.	24 hrs.	
30	3 hrs.	24 hrs.	21 hrs.
31	0 hrs.	24 hrs.	24 hrs.

FIGURE T

AVERAGE MONTHLY IRON CONTENT OF THE RAW SEWAGE FOR THE POLYMER TREATMENT PERIOD OF 1968



G. COST ANALYSIS

In order that a complete treatment of this project may be obtained, a brief economic consideration will be presented. The object of this consideration is a definition of the costs of achieving the various benefits attributed to the polymer addition. In this treatment, only direct costs will be considered, as opposed to facility costs, and general and administrative costs. By direct costs are meant those costs incurred daily on a routine schedule and directly attributable to the physical requirements of the unit process, i.e. operation labor and supplies, maintenance labor and materials, and metered power consumption.

The direct costs for the control (background) period will be the numerical average of those costs for the years 1966 and 1967, to correspond to the data treatment already presented. Although it is realized that direct costs are increasing at the rate of about 7% per year (due to increased labor and material costs), a meaningful cost study must neglect this 7% increase so that comparison can be made on equal grounds; that is, the direct costs excluding polymer costs for the year 1968 will be assumed to be equivalent to the 1966-67 average.

From the project costs it is seen that the total polymer cost was $102,303.00 for the 9-1/2 months of polymer treatment. With this cost as the basic unit additional cost incurred during polymer treatment, Table IV compares the direct costs incurred per unit of pollutant removed in both primary and secondary treatment. It is apparent that the primary treatment direct costs during the polymer period are increased by the cost of polymer, but are decreased by the extra units of pollutant removed with the polymer. Also, the secondary treatment direct costs during polymer treatment are increased by the lessened units of pollutant removed, but are decreased by the blower power savings. These power savings are shown in Figure U, and are attributable to the lessened demand for

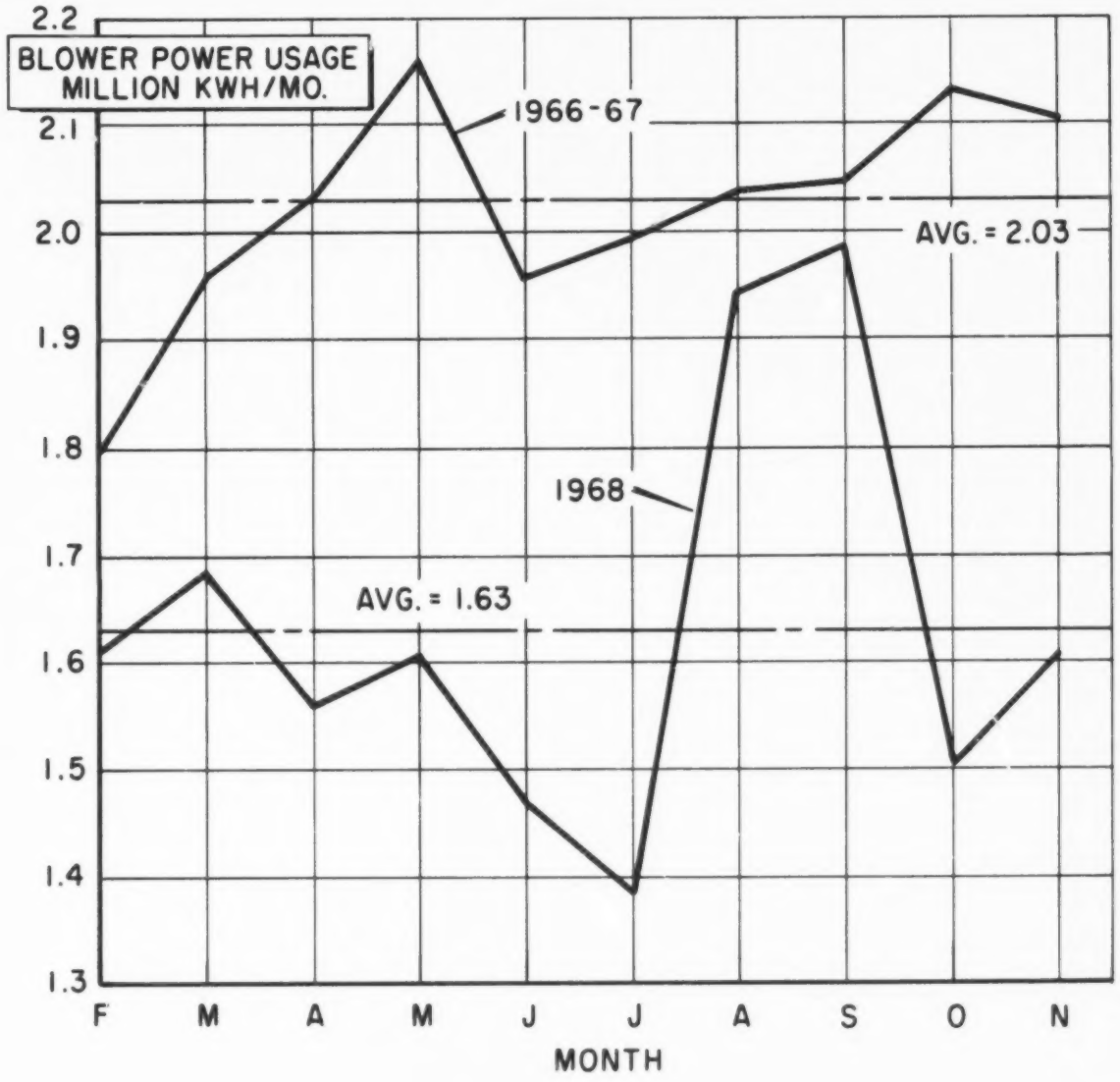
TABLE IV

COST ANALYSIS

	Control Period	Polymer Demonstration Period
DIRECT COST per Ton SS Removed in PRIMARY Treatment	$ 10.58	$ 14.85
DIRECT COST per Ton B.O.D. Removed in PRIMARY Treatment	16.46	20.47
DIRECT COST per Ton SS Removed in SECONDARY Treatment	21.22	22.97
DIRECT COST per Ton BOD Removed in SECONDARY Treat.	33.65	30.10
TOTAL DIRECT COST (Prim & Sec) per Ton SS Removed	31.80	37.82
TOTAL DIRECT COST (Prim & Sec) per Ton B.O.D. Removed	50.11	50.57

FIGURE U

MONTHLY BLOWER POWER USAGE



oxygen as a result of the increased primary treatment during polymer addition. It is seen that a power savings of 400,000 KWH per month was attained, and at the prevailing Cleveland rate of 0.83 cents per KWH a savings of $3,320 per month is noted.

It is apparent that the cost per unit of pollutant removed in primary treatment for the polymer period is in the order of $4 per ton higher than for the control period. This reflects the increased direct cost due to the cost of the polymer. The direct costs reported for secondary treatment during the polymer period are in the order of $1 per ton lower than for the control period, reflecting the power savings attained during polymer treatment.

Also shown in Table IV are the total direct costs for primary plus secondary treatment per ton of pollutant removed. The total direct cost for unit of SS removed during polymer treatment is about $6 per ton higher, while that for unit BOD removed is only about $0.50 higher. However, an additional 4 tons per day of SS and 5 tons per day BOD were kept from Lake Erie during polymer treatment due to the increased treatment efficiency.

Two other considerations must be mentioned as they will affect this cost analysis. The cost of power to the City of Cleveland's operating departments (including waste treatment) is necessarily lower than that supplied by a private utility. This is because Cleveland generates its own power for city governmental and utility usage. The figure of 0.83 cents per KWH for city power can be adjusted upwards to 1 cent per KWH or higher for private utilities. Secondly, the cost of polymer of $1.60 per pound does not reflect a 15% decrease in price to $1.35 per pound for carload lots. If both these factors were taken into account, the polymer cost analysis would be more favorable. For example, using power at 1 cent per KWH and polymer at $1.35 per pound, the total direct cost for SS removal would be $35.85 per ton, while that for BOD removal would be $48.02

per ton. Thus the average ton of SS removed would cost about $4 per ton more during polymer treatment, while the average ton of BOD removed with polymer would cost about $2 less per ton.

The City of Cleveland, through Easterly Contract Number 136, is adding additional primary tankage capacity to the Easterly Center in order to attain increased primary treatment at present raw sewage flow conditions. Construction on this contract was started in January, 1969. Polymer treatment as practiced during this demonstration would provide the same degree of primary treatment as the Contract 136 expansion. It is thus possible to compare the cost of capital facilities to that of polymer treatment. It was felt that all costs not strictly necessary to the primary process function should be subtracted from the total Contract 136 cost. Such a list was prepared as follows:

Non-Primary Costs (Items segregated as not strictly necessary to the primary process function

Number	Item	Cost
22	Roadways	$ 19,500
23	Brick Masonry	125
25	Building	592,000
26	Fencing	8,500
27	Removal of Existing Facilities	120,000
30	Pumping Equipment Installation	312,404
36	Ozone Generator	22,500
37	Elevator Installation	20,500
38	Painting Installation	40,000
39	Temporary Operating Facilities	131,381
41	Heating and Ventilation	220,000
	Total	$1,486,910

The following computation can then be made to obtain the cost that can be applied directly to the primary process.

Total Project Cost	$6,147,145
Total Non-Primary	1,486,910
Difference	$4,660,235 - Directly to Primary

The total cost of money at a basic 4.5% interest rate and amortization over 25 years would yield a charge of 6.744% per year, for 25 years. Thus the yearly charge would be -

$$4,660,235 \times \frac{\$6.744}{100} = \$314,283.888$$

or annual payment: $314,284.00.

Polymer costs per year, at 0.25 ppm polymer and $1.615 per pound, at an average flow of 130 MGD, would be -

$$0.25 \times 8.34 \times 130 \times 1.615 \times 365 = \$159,000$$

Thus, polymer treatment would save approximately $155,000 per year.

V. REFERENCES

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VI. APPENDIX

A. CONTROL AND PROJECT DATA

(All following pages)

AVERAGE MONTHLY FLOWS
(MGD)

	1961	1962	1963	1964	1965	1966	1967	Avg. '61-'67	1968
Jan.	104	110	106	111	118	106	112		123
Feb.	121	113	106	107	117	122	122	115	116
March	122	115	125	125	123	120	135	124	128
April	125	107	106	123	112	122	126	117	116
May	113	111	104	112	109	116	129	113	122
June	120	118	102	116	119	122	126	118	123
July	117	117	113	124	118	126	126	120	131
Aug.	122	117	114	117	124	128	126	121	135
Sept.	117	119	102	110	116	119	119	115	126
Oct.	108	117	105	105	115	110	118	111	121
Nov.	107	114	102	99	112	125	126	112	134
Dec.	105	114	102	105	111	132	120		___
Total	1172	1148	1079	1138	1165	1210	1253		1252
Avg. Feb.-Nov.	117	115	108	114	117	121	125		125

AVERAGES OF AVERAGE DAILY FLOW PER MONTH
(MGD)

Flow	Total 1961 thru 1965	Avg. 1961-1965	Total 1966-1967	Avg. 1966-1967	Avg. 1968
		February			
Raw	564	113	244	122	116
		March			
Raw	610	122	255	128	128
		April			
Raw	573	115	248	124	116
		May			
Raw	549	110	245	122	122
		June			
Raw	575	115	248	124	123
		July			
Raw	589	118	252	126	131
		August			
Raw	594	119	254	127	135
		September			
Raw	564	113	238	119	126
		October			
Raw	550	110	228	114	121
		November			
Raw	534	107	251	126	134
			Total 1966-1968	Avg. 1966-1968	
		December			
Raw	537	107			
		January			
Raw	549	110	341	114	

AVERAGE MONTHLY POLYMER DOSAGES

MONTH	Polymer Dosage (ppm)
February	0.22
March	0.20
April	0.28
May	0.24
June	0.26
July	0.16
August	0.14
September	0.24
October	0.19
November	0.21
Average	0.21

MONTHLY SUSPENDED SOLIDS VALUES
(ppm)

		1961	1962	1963	1964	1965	1966	1967	Avg. '61-'67	1968
Feb.	Raw	203	179	173	154	149	144	163	166	176
	P.E.	145	147	124	137	134	113	132	133	85
	F.E.	30.0	24.8	24.4	22.4	26.2	28.1	30.0	26.6	31.3
March	Raw	206	174	218	155	153	144	158	173	175
	P.E.	176	143	143	146	128	106	119	137	77
	F.E.	28.2	37.6	28.9	25.8	24.1	30.4	26.5	28.8	33
April	Raw	197	198	258	145	155	158	147	180	158
	P.E.	204	159	153	131	121	110	103	140	72
	F.E.	31.9	39.4	25.0	26.8	22.7	20.8	24.6	27.3	12.0
May	Raw	206	199	205	142	161	155	146	173	170
	P.E.	175	143	145	112	107	108	99	127	87
	F.E.	20.7	24.2	29.5	20.0	18.3	23.8	18.1	22.2	14.7
June	Raw	189	189	177	135	176	146	157	167	149
	P.E.	161	128	122	110	108	111	99	120	83
	F.E.	51.0	21.5	36.4	28.0	26.9	21.2	16.2	28.7	23.8
July	Raw	268	161	155		168	157	157	178	136
	P.E.	134	119	97		108	94	88	107	72
	F.E.	16.1	37.3	23.6		19.8	25.6	14.6	22.8	16.6
Aug.	Raw	172	181	157	139	165	160	121	156	150
	P.E.	108	111	98	117	91	88	69	97	72
	F.E.	14.7	19.8	19.7	13.0	21.2	15.7	13.7	16.8	14.2
Sept.	Raw	190	172	181	158	153	170	135	165	148
	P.E.	107	101	111	107	95	96	69	98	70
	F.E.	22.4	14.0	15.1	12.5	23.7	15.6	20.5	17.7	18.9
Oct.	Raw	227	168	207	149	155	157	144	172	177
	P.E.	121	106	123	109	102	91	81	105	78
	F.E.	16.8	21.2	18.6	16.2	20.8	23.1	20.2	19.6	30.9
Nov.	Raw	219	158	158	163	148	147	143	162	133
	P.E.	120	114	122	119	114	109	72	110	71
	F.E.	21.5	19.4	20.3	13.8	20.8	30.7	17.6	20.6	22.4
Dec.	Raw	184	145	156	155	143	162	140		
	P.E.	148	108	125	135	119	119	91		
	F.E.	23.7	15.6	28.7	17.1	29.3	27.2	16.8		
Jan.	Raw	195	199	148	160	131	137	172		135
	P.E.	163	147	122	146	120	112	112		90
	F.E.	31.5	31.6	22.3	36.4	24.1	25.3	25.4		21.5
						Avg. (Feb.-Nov.)			169	157
									117	77
									23.1	21.8

*P.E. = Primary Effluent
**F.E. = Final Effluent

Note: July 1964 SS data not used. Very high values due to construction work.

MONTHLY BOD VALUES
(ppm)

		1961	1962	1963	1964	1965	1966	1967	Avg. '61-'67	1968
Jan.	Raw	219	196	128	185	157	109	126		135
	P.E.*	176	153	83	141	122	67	82		82
	F.E.**	28.3	19.8	14.8	27.1	25	23	34		22
Feb.	Raw	231	199	131	204	169	111	102	164	151
	P.E.	179	165	82	147	132	76	87	124	71
	F.E.	30.4	10.1	16.2	23.4	18	23	28	21	19
March	Raw	186	210	150	176	173	105	104	158	141
	P.E.	140	141	107	132	128	77	80	115	74
	F.E.	23.9	16.2	19.0	18.0	19	17	23	19	18
April	Raw	146	188	162	152	162	112	110	147	127
	P.E.	113	132	103	121	117	64	82	104	79
	F.E.	18.3	16.2	16.6	17.7	19	14	21	18	17
May	Raw	209	192	199	208	177	106	127	174	127
	P.E.	131	142	110	161	113	59	77	113	77
	F.E.	16.9	18.6	18.3	21.3	16	22	26	20	25
June	Raw	190	184	181	200	158	107	107	161	124
	P.E.	115	127	153	152	111	64	74	113	61
	F.E.	25.2	17.5	21.8	19.3	23	23	24	22	27
July	Raw	194	166	153	165	120	77	91	138	128
	P.E.	132	132	121	122	76	73	60	102	69
	F.E.	17.0	39.3	18.6	14.0	12	20	21	20	28
Aug.	Raw	188	170	132	150	105	70	96	130	113
	P.E.	154	128	78	94	40	49	56	86	63
	F.E.	15.5	15.3	20.6	11	12	19	20	16	19
Sept.	Raw	204	165	185	158	83	102	103	143	109
	P.E.	130	102	106	97	37	74	59	86	52
	F.E.	19.9	14.0	22.4	15	20	17	27	19	22
Oct.	Raw	187	165	189	148	115	98	114	145	120
	P.E.	146	133	112	94	66	76	65	99	61
	F.E.	17.8	14.5	22.3	12	31	25	26	21	26
Nov.	Raw	205	156	176	190	116	105	123	153	111
	P.E.	160	112	119	97	66	81	65	100	58
	F.E.	16.3	13.4	19.5	13	26	25	25	20	23
Dec.	Raw	202	147	223	173	119	91	136		
	P.E.	147	111	167	137	71	75	83		
	F.E.	18.5	18.8	21.6	15	28	26	27		
					Avg. (Feb.-Nov.)				151	125
									104	67
									20	22

*Primary Effluent
**Final Effluent

MONTHLY SS REMOVAL EFFICIENCIES

(% REMOVALS)

Removal	1961	1962	1963	1964	1965	1966	1967	1968
				January				
Primary	16.4	26.1	17.6	8.7	8.4	18.3	34.9	32.6
Final	83.8	84.1	84.9	77.3	81.7	81.5	82.5	84.1
				February				
Primary	28.6	17.9	29.4	11.0	10.1	21.5	19.0	51.7
Final	85.2	86.1	86.0	85.4	82.5	80.6	81.7	82.2
				March				
Primary	14.6	17.8	34.4	5.8	16.4	26.4	24.6	56.0
Final	86.3	78.4	86.7	83.5	84.3	78.8	83.2	81.1
				April				
Primary	0	19.7	40.8	9.7	22.7	30.4	29.9	54.4
Final	83.8	80.3	90.2	81.6	85.3	86.9	83.3	92.4
				May				
Primary	15.0	28.1	28.3	22.5	33.5	30.3	32.2	55.6
Final	90.0	87.8	85.6	85.8	88.4	84.7	87.6	91.4
				June				
Primary	14.8	32.3	31.1	18.5	38.7	24.0	36.9	44.3
Final	73.0	88.6	79.4	79.3	84.6	85.5	89.7	84.0
				July(1)				
Primary	50.0	26.1	37.4	10.1	35.7	40.2	43.9	52.2
Final	94.0	76.8	84.5	25.3	87.5	83.7	90.7	87.8
				August(2)				
Primary	37.2	38.7	37.6	15.8	44.8	45.0	43.0	52.0
Final	91.5	89.1	87.4	90.8	87.3	91.9	88.7	91.3
				September				
Primary	43.7	41.3	38.7	32.3	37.9	49.4	48.9	47.3
Final	87.4	91.9	91.6	92.2	84.6	91.2	84.8	87.2
				October				
Primary	46.7	30.4	40.6	26.8	34.2	42.0	43.8	55.9
Final	92.6	86.9	91.0	89.4	86.6	85.2	86.0	82.5
				November				
Primary	45.2	27.9	22.8	27.0	22.9	25.8	49.7	46.6
Final	90.2	87.8	87.2	91.6	85.8	79.3	87.7	83.2
							Avg. =	86.3
				December				
Primary	19.6	25.5	19.9	12.9	16.8	26.5	35.0	
Final	87.3	89.3	81.7	89.0	79.5	83.2	88.0	

(1) July 1968 data neglects that from July 7, 14, 22, and 23. On these four days, the raw sewage sampler did not operate properly.

(2) Final effluent SS and BOD not included for August 20. The samplers were flushed and cleaned improperly on this day.

AVERAGES FOR MONTHLY SS REMOVAL EFFICIENCIES

(% REMOVALS)

Removal	1961 thru 1965 Total	1961 thru 1965 Avg.	1966 thru 1967 Total	1966 thru 1967 Avg.	Avg. 1961-1967
			February		
Primary	97.0	19.4	40.5	20.2	19.6
Final	425.2	85.0	162.3	81.2	83.9
			March		
Primary	89.0	17.8	51.0	25.5	20.0
Final	419.2	83.8	162.0	81.0	83.0
			April		
Primary	92.9	18.6	60.3	30.2	21.9
Final	421.2	84.2	170.2	85.1	84.5
			May		
Primary	127.4	25.5	62.5	31.2	27.1
Final	437.6	87.5	172.3	86.2	87.1
			June		
Primary	135.4	27.1	60.9	30.4	28.0
Final	404.9	81.0	175.2	87.6	82.9
			July		
Primary	159.3	31.9	84.1	42.0	34.8
Final	368.1	73.6	174.4	87.2	77.5
			August		
Primary	174.1	34.8	88.0	44.0	37.4
Final	446.1	89.2	180.6	90.3	89.5
			September		
Primary	193.9	38.8	98.3	49.2	41.7
Final	447.7	89.5	176.0	88.0	89.1
			October		
Primary	178.7	35.7	85.8	42.9	37.8
Final	446.5	89.3	171.2	85.6	88.2
			November		
Primary	145.8	29.2	75.5	37.8	31.6
Final	442.6	88.5	167.0	83.5	87.1
			Avg.	85.6	85.3

Removal	1966 thru 1968 Total	1966 thru 1968 Avg.
	December	
Primary	94.7	18.9
Final	426.8	85.4
	January	
Primary	77.2	15.4
Final	411.8	82.4
	85.8	28.6
	248.1	82.7

MONTHLY BOD REMOVAL EFFICIENCIES

(% REMOVALS)

Removal	1961	1962	1963	1964	1965	1966	1967	1968
				January				
Primary	19.6	21.9	35.2	23.8	22.3	38.5	34.9	39.3
Final	87.1	89.9	88.4	85.4	84.2	79.0	73.0	83.7
				February				
Primary	22.5	17.1	37.4	27.9	21.9	31.5	14.7	53.0
Final	86.8	94.8	87.6	88.6	89.3	79.3	72.5	87.4
				March				
Primary	24.7	32.8	28.7	25.0	26.0	25.9	23.1	47.5
Final	87.1	92.3	87.3	89.7	89.2	83.8	77.9	87.2
				April				
Primary	21.0	29.8	36.4	20.4	27.8	42.8	25.5	37.8
Final	87.2	91.4	89.8	88.3	88.3	87.5	80.9	86.6
				May				
Primary	37.3	26.0	44.7	22.6	36.1	40.0	39.3	39.4
Final	91.9	90.3	90.8	89.8	88.7	79.2	79.5	80.3
				June				
Primary	39.5	31.0	15.5	24.0	36.1	40.2	30.8	50.8
Final	86.7	90.5	87.8	90.3	85.5	78.2	77.6	78.2
				July(1)				
Primary	32.0	20.5	20.8	26.1	36.7	5.2	34.1	51.0
Final	91.2	76.3	87.5	91.6	90.0	77.4	76.9	78.1
				August(2)				
Primary	12.7	24.7	40.9	37.3	62.9	52.0	41.7	44.2
Final	91.1	91.0	84.4	92.7	88.6	88.0	79.2	83.2
				September				
Primary	36.3	38.2	42.7	38.7	35.3	27.5	42.7	52.3
Final	90.2	91.6	87.9	90.6	82.3	83.3	73.8	79.8
				October				
Primary	21.9	19.4	40.7	36.5	42.7	22.4	43.0	49.2
Final	90.7	91.3	88.2	91.9	73.0	74.5	77.2	78.3
				November				
Primary	21.9	28.2	32.4	48.8	43.1	30.4	47.2	47.7
Final	92.1	91.3	89.4	93.3	77.6	76.3	79.7	79.3
				December				
Primary	27.2	24.5	24.0	26.6	40.3	17.6	39.0	
Final	90.8	87.2	90.3	91.4	76.5	71.4	80.1	

(1) July 1968 data neglects that from July 7, 14, 22, and 23. On these four days, the raw sewage sampler did not operate properly.

(2) Final effluent SS and BOD not included for August 20. The samplers were flushed and cleaned improperly on this day.

AVERAGES FOR MONTHLY BOD REMOVAL EFFICIENCIES

(% REMOVALS)

Removal	1961 thru 1965 Total	1961 thru 1965 Avg.	1966 thru 1967 Total	1966 thru 1967 Avg.	Avg. 1961-1967
			February		
Primary	126.8	25.4	46.2	23.1	24.7
Final	447.1	89.4	151.8	75.9	85.6
			March		
Primary	137.2	27.4	49.0	24.5	26.6
Final	445.6	89.1	161.7	80.8	86.8
			April		
Primary	135.4	27.1	68.3	34.2	29.1
Final	445.0	89.0	168.4	84.2	87.6
			May		
Primary	166.7	33.3	79.3	39.6	35.1
Final	451.5	90.3	158.7	79.4	87.2
			June		
Primary	146.1	29.2	71.0	35.5	31.0
Final	440.8	88.2	155.8	77.9	85.2
			July		
Primary	136.1	27.2	39.3	19.6	25.1
Final	436.6	87.3	154.3	77.2	84.4
			August		
Primary	178.5	35.7	93.7	46.8	38.9
Final	447.8	89.6	167.2	83.6	87.9
			September		
Primary	191.2	38.2	70.2	35.1	37.3
Final	442.6	88.5	157.1	78.6	85.7
			October		
Primary	161.2	32.2	65.4	32.7	32.4
Final	435.1	87.0	151.7	75.8	83.8
			November		
Primary	174.4	34.9	77.6	38.8	36.0
Final	443.7	88.7	156.0	78.0	85.7
			December		
Primary	142.6	28.5			
Final	436.2	87.2			

Removal	1966 thru 1968 Total	1966 thru 1968 Avg.
	January	
Primary	112.7	37.6
Final	335.7	111.9

TOTAL PHOSPHATE (ppm)

Figures Based on Samples Taken Once a Week (Composite)

Month	Item	1966	1967	1966 thru 1967 Total	1966 thru 1967 Avg.	1968
Jan.	Raw	21.7*	No			21.4
	Settled	19.0*	Data			17.6
	Effluent	14.5*				13.3
Feb.	Raw	21.5*	No			23.5*
	Settled	17.7*	Data			17.8*
	Effluent	10.8*				14.6*
March	Raw	20.4*	No			18.0*
	Settled	18.2*				14.9*
	Effluent	13.5*				11.7*
April	Raw	20.3*	No			26.1*
	Settled	18.4*	Data			20.1*
	Effluent	12.6*				14.8*
May	Raw	17.2*	No			23.6*
	Settled	15.2*	Data			16.4*
	Effluent	12.1*				11.9*
June	Raw	17.8*	19.3	37.1	18.6	No
	Settled	16.0*	18.5	34.5	17.2	Data
	Effluent	12.7*	11.1	23.8	11.9	
July	Raw	23.8	19.3	43.1	21.6	No
	Settled	20.3	17.3	37.6	18.8	Data
	Effluent	15.0	11.8	26.8	13.4	
Aug.	Raw	21.2	17.8	39.0	19.5	No
	Settled	17.4	17.4	34.8	17.4	Data
	Effluent	11.0	12.5	23.5	11.8	
Sept.	Raw	28.6	19.8	48.4	24.2	No
	Settled	22.1	15.4	37.5	18.8	Data
	Effluent	11.1	11.2	22.3	11.2	
Oct.	Raw	28.1	22.0	50.1	25.0	No
	Settled	20.2	18.5	38.7	19.4	Data
	Effluent	11.7	10.7	22.4	11.2	
Nov.	Raw	20.8	20.3	41.1	20.6	No
	Settled	17.7	15.6	33.3	16.6	Data
	Effluent	11.2	12.0	23.2	11.6	
Dec.	Raw	22.5	21.8	44.3	22.2	No
	Settled	19.6	17.8	37.4	18.7	Data
	Effluent	13.3	13.3	26.6	13.3	

*These figures based on daily sampling (not weekends).

21.1	22.5
18.0	17.4
12.3	13.2

DISSOLVED PHOSPHATE (ppm)

Figures Based on Samples Taken Once a Week (Composite)

Month	Item	1966	1967	1966 thru 1967 Total	1966 thru 1967 Avg.	1968
Jan.	Raw	10.3*	No			13.8
	Settled	9.8*	Data			12.2
	Effluent	8.2	No			10.2
Feb.	Raw	8.3*	No			11.7*
	Settled	7.5*	Data			10.0*
	Effluent	6.5*				7.9*
March	Raw	5.7*	No			6.6*
	Settled	5.7*	Data			5.6*
	Effluent	5.2*				5.1*
April	Raw	7.0*	No			11.7*
	Settled	7.4*	Data			8.4*
	Effluent	7.3*				6.5*
May	Raw	7.9*	No			14.9*
	Settled	7.3*	Data			10.9*
	Effluent	6.7*				8.5*
June	Raw	8.9*	10.2	19.1	9.6	No
	Settled	8.8*	9.6	18.4	9.2	Data
	Effluent	8.5*	8.2	16.7	8.4	
July	Raw	16.2	12.5	28.7	14.4	No
	Settled	14.6	13.9	28.5	14.2	Data
	Effluent	12.0	10.6	22.6	11.3	
Aug.	Raw	10.1	10.9	21.0	10.5	No
	Settled	9.7	12.8	22.5	11.2	Data
	Effluent	8.6	9.7	18.3	9.2	
Sept.	Raw	11.0	9.5	20.5	10.2	No
	Settled	10.3	8.6	18.9	9.4	Data
	Effluent	9.9	8.1	18.0	9.0	
Oct.	Raw	12.4	12.1	24.5	12.2	No
	Settled	11.0	10.5	21.5	10.8	Data
	Effluent	8.0	8.9	16.9	8.4	
Nov.	Raw	11.6	11.1	22.7	11.4	No
	Settled	10.7	9.7	20.4	10.2	Data
	Effluent	8.4	8.5	16.9	8.4	
Dec.	Raw	11.4	11.0	22.4	11.2	No
	Settled	11.0	10.4	21.4	10.7	Data
	Effluent	8.1	9.1	17.2	8.6	

*These figures based on daily sampling (not weekends).

					9.9	11.8
					9.5	9.4
					8.1	7.6

EASTERLY TREATMENT DATA

FREE AMMONIA (ppm)

Month	Item	1966	1967	1966 thru 1967 Total	1966 thru 1967 Avg.	1968
Jan.	Raw	16	19	35	18	14
	Settled	12	12	24	12	12
	Effluent	14	6	20	10	10
Feb.	Raw	14	14	28	14	14
	Settled	11	9	20	10	12
	Effluent	13	10	23	12	13
March	Raw	15	13	28	14	15
	Settled	10	8	18	9	11
	Effluent	13	10	23	12	14
April	Raw	14	12	26	13	18
	Settled	10	9	19	10	14
	Effluent	12	10	22	11	17
May	Raw	16	14	30	15	16
	Settled	12	9	21	10	12
	Effluent	13	7	20	10	9
June	Raw	15	12	27	14	17
	Settled	11	7	18	9	12
	Effluent	11	6	17	8	10
July	Raw	11	10	21	10	12
	Settled	8	6	14	7	10
	Effluent	8	4	12	6	11
Aug.	Raw	11	11	22	11	13
	Settled	8	6	14	7	9
	Effluent	5	6	11	6	8
Sept.	Raw	16	15	31	16	14
	Settled	10	9	19	10	10
	Effluent	6	9	15	8	5
Oct.	Raw	19	16	35	18	13
	Settled	10	9	19	10	9
	Effluent	5	7	12	6	7
Nov.	Raw	15	18	33	16	13
	Settled	10	10	20	10	8
	Effluent	3	6	9	4	8
Dec.	Raw	10	14	24	12	15
	Settled	7	11	18	9	11
	Effluent	2	7	9	4	11

	1966-1967 (Feb.-Nov.) Total	1966-1967 (Feb.-Nov.) Avg.	1968 (Feb.-Nov.) Avg.
Raw	141	14	14.5
Settled	92	9	11.0
Effluent	83	8	10.0

EASTERLY TREATMENT DATA

EFFLUENT NITRITE AND NITRATE (ppm)

Month	Item	1966	1967	Total	Average	1968
Jan.	Nitrite	0.36	2.9	3.26	1.63	1.0
	Nitrate	2.6	3.2	5.80	2.90	2.1
Feb.	Nitrite	0.21	0.8	1.01	0.50	0.4
	Nitrate	2.7	2.0	4.70	2.35	2.2
March	Nitrite	0.12	0.37	0.49	0.24	0.4
	Nitrate	2.4	2.4	4.80	2.40	3.4
April	Nitrite	0.22	0.42	0.64	0.32	0.5
	Nitrate	2.5	2.0	4.50	2.25	2.7
May	Nitrite	0.9	1.5	2.40	1.20	0.6
	Nitrate	2.3	2.3	4.60	2.30	4.5
June	Nitrite	0.7	1.8	2.50	1.25	1.6
	Nitrate	2.2	2.1	4.30	2.15	2.9
July	Nitrite	1.5	2.2	3.70	1.85	1.0
	Nitrate	2.0	1.8	3.80	1.90	1.3
Aug.	Nitrite	0.8	0.7	1.50	0.75	2.0
	Nitrate	3.7	2.3	6.00	3.00	2.5
Sept.	Nitrite	0.3	1.5	1.80	0.90	1.6
	Nitrate	5.0	1.9	6.90	3.45	5.0
Oct.	Nitrite	0.26	2.0	2.26	1.13	0.4
	Nitrate	6.1	3.5	9.60	4.80	4.5
Nov.	Nitrite	0.39	1.4	1.79	0.90	1.6
	Nitrate	7.2	6.0	13.20	6.60	3.3
Dec.	Nitrite	0.91	1.5	2.41	1.20	0.7
	Nitrate	5.3	5.0	10.30	5.15	2.8

	1966-1967 (Feb.-Nov.)		1968 (Feb.-Nov.)	
	Total	Avg.	Total	Avg.
Nitrite	9.04	0.90	10.10	1.01
Nitrate	31.20	3.12	32.30	3.23

EASTERLY TREATMENT DATA

CHEMICAL OXYGEN DEMAND (ppm)

Month	Item	1966	1967	Total	Average	1968
Jan.	Raw	370	465	835	418	346
	Settled	273	252	525	262	245
	Effluent	89	82	171	86	101
Feb.	Raw	358	349	707	354	383
	Settled	259	261	520	260	205
	Effluent	98	102	200	100	95
March	Raw	357	376	733	366	345
	Settled	257	264	521	260	194
	Effluent	91	104	195	98	88
April	Raw	369	345	714	357	361
	Settled	234	242	476	238	194
	Effluent	66	83	149	74	62
May	Raw	364	386	750	375	320
	Settled	228	219	447	224	201
	Effluent	81	74	155	78	61
June	Raw	338	385	723	362	329
	Settled	219	209	428	214	188
	Effluent	75	68	143	72	82
July	Raw	295	323	618	309	293
	Settled	174	182	356	178	166
	Effluent	71	60	131	66	78
Aug.	Raw	288	336	624	312	243
	Settled	167	178	345	172	125
	Effluent	53	74	127	64	44
Sept.	Raw	352	348	700	350	278
	Settled	189	193	382	191	143
	Effluent	54	93	147	74	57
Oct.	Raw	354	380	734	367	333
	Settled	218	208	426	213	155
	Effluent	72	88	160	80	66
Nov.	Raw	327	380	707	354	279
	Settled	227	198	425	212	153
	Effluent	79	92	171	86	60
Dec.	Raw	337	367	704	352	291
	Settled	227	247	474	237	218
	Effluent	82	79	161	80	120

	1966-1967 (Feb.-Nov.) Total	1966-1967 (Feb.-Nov.) Avg.	1968 Avg.
Raw	3506	351	316
Settled	2162	216	172
Effluent	792	79	69

Fe CONCENTRATION IN
RAW AND SETTLED SEWAGE
(ppm of Total Iron)

		1966	1967	Σ	Average	1968
Jan.	Raw	1.7	2.5	6.6*	2.2*	2.4
	Settled	0.9	1.5	4.3*	1.4*	1.9
Feb.	Raw	2.1	2.8	4.9	2.4	3.1
	Settled	1.2	1.8	3.0	1.5	1.6
March	Raw	2.0	4.0	6.0	3.0	4.1
	Settled	1.2	1.9	3.1	1.6	2.0
April	Raw	2.0	3.0	5.0	2.5	3.7
	Settled	1.1	1.9	3.0	1.5	2.0
May	Raw	2.0	2.5	4.5	2.2	2.2
	Settled	1.3	1.8	3.1	1.6	1.7
June	Raw	2.1	2.8	4.9	2.4	2.1
	Settled	1.4	1.3	2.7	1.4	1.3
July	Raw	2.3	2.1	4.4	2.2	1.8
	Settled	1.3	1.2	2.5	1.2	0.9
Aug.	Raw	2.5	2.2	4.7	2.4	0.8
	Settled	1.2	1.1	2.3	1.2	0.5
Sept.	Raw	2.4	2.0	4.4	2.2	0.9
	Settled	1.5	1.5	3.0	1.5	0.6
Oct.	Raw	2.1	2.4	4.5	2.2	4.6
	Settled	1.5	1.5	3.0	1.5	2.6
Nov.	Raw	2.3	1.7	4.0	2.0	2.6
	Settled	1.6	1.2	2.8	1.4	1.5
Dec.	Raw	2.4	2.5	*		
	Settled	1.6	1.7	*		

*Σ and average for 1966 and 1967.

MIXED LIQUOR SUSPENDED SOLIDS (SS)

(ppm)

	1966	1967	1966 thru 1967 Total	1966 thru 1967 Avg.*	1968
January					
Avg. SS	1840	1980	5380	1793	1560
Index	89	77	217	72	51
February					
Avg. SS	1530	1530	3060	1530	1260
Index	65	52	117	58	59
March					
Avg. SS	1780	1460	3240	1620	1830
Index	88	52	140	70	66
April					
Avg. SS	1930	1540	3470	1735	1370
Index	89	53	142	71	83
May					
Avg. SS	1780	1720	3500	1750	2030
Index	72	69	141	70	103
June					
Avg. SS	1260	1830	3090	1545	1230
Index	68	83	151	76	116
July					
Avg. SS	1520	1640	3160	1580	1310
Index	104	88	192	96	155
August					
Avg. SS	2030	760	2790	1395	1720
Index	82	144	226	113	87
September					
Avg. SS	2030	1050	3080	1540	2020
Index	77	76	153	76	96
October					
Avg. SS	2580	1440	4020	2010	1780
Index	88	77	165	82	145
November					
Avg. SS	2540	1460	4000	2000	1470
Index	81	72	153	76	155
December					
Avg. SS	2540	1819			
Index	71	67			
			Avgs.	1670	1602
				79	107

*Total and Average for Jan. and Dec. are for 1966, 1967, and 1968.

DISSOLVED OXYGEN LEVELS

All Values in ppm

A.E. = Effluent of Aeration Tank
F.E. = Final Effluent

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.									
A.E.	4.0	6.7	3.8	2.6	3.5	2.9	3.1		4.5
F.E.	1.9	3.9	2.5	1.9	3.3	2.1	1.9		2.5
Feb.									
A.E.	4.9	4.2	3.9	2.8	3.1	3.8	4.5	4.2	4.3
F.E.	2.9	2.6	2.4	2.4	2.0	2.7	2.9	2.8	2.5
March									
A.E.	4.3	3.8	5.2	3.6	3.4	3.2	5.2	4.2	5.6
F.E.	2.5	2.1	3.7	4.0	2.4	2.2	3.5	2.8	3.7
April									
A.E.	4.5	3.9	4.2	4.5	3.2	4.4	4.2	4.3	5.1
F.E.	2.6	2.3	2.9	4.3	2.2	2.6	2.8	2.7	3.0
May									
A.E.	3.8	4.2	2.8	3.6	4.0	3.5	3.9	3.7	4.5
F.E.	3.8	2.1	1.9	2.8	2.5	2.2	2.5	2.4	2.6
June									
A.E.	2.8	3.9	3.8	2.9	4.2	3.3	2.5	2.9	3.6
F.E.	1.6	2.1	2.2	1.9	2.6	2.4	1.7	2.0	1.8
July									
A.E.	3.6	2.7	3.4	2.7	3.3	2.9	2.2	2.6	3.2
F.E.	2.0	1.8	2.5	1.9	2.2	2.6	1.7	2.2	1.6
Aug.									
A.E.	4.4	3.0	2.2	2.6	4.0	2.1	2.2	2.2	2.4
F.E.	2.1	2.5	3.4	1.7	2.5	1.9	1.7	1.8	1.6
Sept.									
A.E.	3.3	3.3	2.2	2.1	3.5	1.7	2.4	2.0	2.9
F.E.	1.7	2.1	1.5	1.9	2.2	1.6	1.7	1.6	1.9
Oct.									
A.E.	3.3	3.3	2.2	3.1	2.5	1.7	2.2	2.0	2.8
F.E.	1.8	2.1	1.5	1.9	1.7	1.6	1.5	1.6	1.7
Nov.									
A.E.	3.8	4.3	2.0	4.0	2.4	2.7	4.6	3.7	3.7
F.E.	2.1	3.0	1.7	2.7	1.7	2.1	2.5	2.3	2.4
							Avg.	3.2	3.8
								2.2	2.3
Dec.									
A.E.	4.4	5.4	1.9	4.0	2.2	3.5	5.6		
F.E.	2.5	4.0	1.9	2.6	1.8	2.4	3.0		

POUNDS OF MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)

1966

	MLSS (ppm) Value	x	% Vol. - Factor	=	MLVSS (ppm) Value	x	8.34 equals	x	Set.Sew.Flow (MGD) Factor	=	MLVSS (Pounds) Value
Jan.	1840		74.2		1365		11384		103.8		1,181,659
Feb.	1530		67.2		1028		8574		119.1		1,021,163
March	1780		68.9		1226		10225		118.9		1,215,752
April	1930		70.5		1361		11351		120.1		1,363,255
May	1780		69.3		1234		10292		113.7		1,170,200
June	1260		67.3		848		7072		119.5		845,104
July	1520		67.2		1021		8515		121.9		1,037,978
Aug.	2030		64.7		1313		10950		124.2		1,359,990
Sept.	2030		67.0		1360		11342		116.4		1,320,209
Oct.	2580		69.0		1780		14845		106.8		1,585,446
Nov.	2540		68.8		1748		14578		121.5		1,771,227
Dec.	2540		67.4		1712		14278		127.6		1,821,873

POUNDS OF MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)

1967

	MLSS (ppm) Value	x	% Vol. - Factor	=	MLVSS (ppm) Value	x	8.34 equals	x	Set.Sew.Flow (MGD) Factor	=	MLVSS (Pounds) Value
Jan.	1980		71.7		1420		11843		109.2		1,293,256
Feb.	1530		61.7		944		7873		118.2		930,589
March	1460		66.2		967		8065		131.3		1,058,934
April	1540		66.0		1016		8473		123.7		1,048,110
May	1720		67.5		1161		9683		124.7		1,207,470
June	1830		67.4		1233		10283		122.9		1,263,781
July	1640		66.1		1084		9041		121.8		1,101,194
Aug.	760		63.8		485		4045		123.8		500,771
Sept.	1050		65.7		690		5755		115.8		666,429
Oct.	1440		67.0		965		8048		116.0		933,568
Nov.	1460		68.1		994		8290		123.9		1,027,131
Dec.	1819		69.0		1255		10467		118.1		1,236,153

POUNDS OF MIXED LIQUOR VOLATILE SUSPENDED SOLIDS (MLVSS)
1968

	MLSS (ppm) Value	x	% Vol. - Factor	=	MLVSS (ppm) Value	x	8.34 equals	x	Set.Sew.Flow (MGD) Factor	=	MLVSS (Pounds) Value
Jan.	1560		66.0		1030		8590		121.0		1,039,390
Feb.	1260		66.7		840		7006		113.9		797,983
March	1830		68.1		1246		10392		124.6		1,294,843
April	1570		67.9		1066		8890		114.4		1,017,016
May	2030		70.4		1429		11918		120.1		1,431,352
June	1230		68.5		843		7031		120.9		850,048
July	1310		68.0		891		7431		129.5		962,314
Aug.	1720		67.3		1158		9658		133.3		1,287,411
Sept.	2020		67.9		1372		11442		123.5		1,413,087
Oct.	1780		70.3		1251		10433		118.0		1,231,094
Nov.	1470		69.5		1022		8523		131.1		1,117,365
Dec.											

CUBIC FEET OF AIR APPLIED PER POUND OF MLVSS

	1966	1967	Σ	Average	1968
Jan.					
C.F. air ($\times 10^6$)	111.8	143.4			122.2
MLVSS (#$\times 10^6$)	1.182	1.293	2.475	1.238	1.039
C.F./# MLVSS	*94.59*	*110.90*	*205.49*	*102.74*	*117.61*
Feb.					
C.F. air ($\times 10^6$)	111.6	141.9			113.5
MLVSS (#$\times 10^6$)	1.021	0.931	1.952	0.976	0.798
C.F./# MLVSS	*109.30*	*152.42*	*261.72*	*130.86*	*142.23*
March					
C.F. air ($\times 10^6$)	111.9	144.7			113.4
MLVSS (#$\times 10^6$)	1.216	1.059	2.275	1.138	1.295
C.F./# MLVSS	*92.02*	*136.64*	*228.66*	*114.33*	*87.57*
April					
C.F. air ($\times 10^6$)	134.0	139.4			110.2
MLVSS (#$\times 10^6$)	1.363	1.048	2.411	1.206	1.017
C.F./# MLVSS	*98.31*	*133.02*	*231.33*	*115.66*	*108.36*
May					
C.F. air ($\times 10^6$)	133.3	137.3			107.8
MLVSS (#$\times 10^6$)	1.170	1.207	2.377	1.188	1.431
C.F./# MLVSS	*113.93*	*113.75*	*227.68*	*113.84*	*75.33*
June					
C.F. air ($\times 10^6$)	132.3	127.2			104.2
MLVSS (#$\times 10^6$)	0.845	1.264	2.109	1.054	0.850
C.F./# MLVSS	*156.57*	*100.63*	*257.20*	*128.60*	*122.59*
July					
C.F. air ($\times 10^6$)	126.7	127.6			88.5
MLVSS (#$\times 10^6$)	1.038	1.101	2.139	1.070	0.962
C.F./# MLVSS	*122.06*	*115.89*	*237.95*	*118.98*	*92.00*
Aug.					
C.F. air ($\times 10^6$)	133.1	130.3			121.5
MLVSS (#$\times 10^6$)	1.360	0.501	1.861	0.930	1.287
C.F./# MLVSS)	*97.87*	*260.08*	*357.95*	*178.98*	*94.41*
Sept.					
C.F. air ($\times 10^6$)	137.9	134.9			131.4
MLVSS (#$\times 10^6$)	1.320	0.666	1.986	0.993	1.413
C.F./# MLVSS	*104.47*	*202.55*	*307.02*	*153.51*	*92.99*
Oct.					
C.F. air ($\times 10^6$)	141.8	135.5			103.3
MLVSS (#$\times 10^6$)	1.585	0.934	2.519	1.260	1.231
C.F./# MLVSS	*89.46*	*145.07*	*234.53*	*117.26*	*83.92*

CUBIC FEET OF AIR APPLIED PER POUND OF MLVSS (Cont.)

Nov.					115.0
C.F. air ($x10^6$)	145.9	143.3			
MLVSS (#$x10^6$)	1.771	1.027	2.798	1.399	1.117
C.F./# MLVSS	*82.38*	*139.53*	*221.91*	*110.96*	*102.95*
Dec.					
C.F. air ($x10^6$)	143.0	143.1			
MLVSS ($x10^6$)	1.822	1.236	3.058	1.529	
C.F./# MLVSS	*78.49*	*115.78*	*194.27*	*97.14*	
MLVSS (#$x10^6$) Totals				11.214	11.401
MLVSS (#$x10^6$) Avg. Daily (Feb.-Nov.)				1.121	1.140
C.F./# MLVSS Totals				*1282.98*	*1002.35*
Cubic Feet air/# MLVSS Avg. (Feb.-Nov.)				*128.30*	*100.24*

MONTHLY SLUDGE PUMPAGE RECORDS
AVERAGE PERCENT PRIMARY SOLIDS

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.	4.5	5.1	4.1	4.1	3.9	3.7	3.4		4.3
Feb.	5.7	5.1	4.3	4.4	4.0	3.0	3.8	3.4	4.0
March	4.3	5.1	4.7	4.3	4.1	3.2	4.2	3.7	3.7
April	5.0	5.8	6.0	3.6	4.2	3.2	5.0	4.1	4.9
May	4.5	5.9	5.1	5.3	4.1	3.7	4.5	4.1	4.5
June	3.7	6.1	4.2	4.8	4.5	4.0	5.1	4.6	4.6
July	4.8	3.7	3.7	4.6	4.2	3.6	4.9	4.2	4.9
Aug.	4.9	3.9	4.4	4.5	4.4	5.0	4.4	4.7	4.5
Sept.	5.0	3.9	5.0	4.7	4.0	4.0	3.7	3.8	4.1
Oct.	6.0	4.1	4.1	4.5	4.5	4.5	4.0	4.2	3.9
Nov.	4.8	4.8	4.9	3.9	4.7	4.0	4.0	4.0	4.2
Dec.	4.3	3.9	4.3	3.8	3.6	4.2	4.6	___	___
					Avg. (Feb.-Nov.)			4.1	4.3

MONTHLY SLUDGE PUMPAGE RECORDS
AVERAGE PERCENT CONCENTRATED SOLIDS

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.	3.0	3.1	2.9	2.7	2.5	2.3	1.9		2.6
Feb.	3.3	3.6	3.2	3.0	2.8	3.0	2.2	2.6	2.2
March	3.5	3.8	3.6	3.1	3.0	2.7	2.7	2.7	2.3
April	3.5	3.3	3.9	2.6	2.8	2.4	2.8	2.6	2.0
May	3.2	3.3	3.5	2.9	2.3	2.5	2.2	2.4	2.0
June	2.6	3.3	2.2	2.5	2.8	2.5	2.6	2.6	2.0
July	2.2	2.8	2.3	2.4	2.6	2.2	3.1	2.6	1.9
Aug.	2.6	3.2	2.1	2.6	2.6	2.4	2.2	2.3	2.0
Sept.	3.9	2.7	2.5	2.6	2.2	2.2	2.2	2.2	2.2
Oct.	3.2	3.0	2.4	2.4	2.5	2.1	2.0	2.0	1.6
Nov.	3.0	3.2	2.6	2.5	2.6	2.3	2.1	2.2	1.3
Dec.	3.1	3.0	2.5	2.7	2.5	2.3	2.1	___	___
						Avg. (Feb.-Nov.)		2.4	2.0

MONTHLY SLUDGE PUMPAGE RECORDS
CONCENTRATED SLUDGE PUMPED IN MG

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.	7.8	10.5	12.8	12.1	12.4	13.9	14.5		12.1
Feb.	11.6	9.1	10.5	9.3	11.5	13.9	11.9	12.9	9.6
March	9.8	11.3	12.2	12.0	9.9	13.8	11.6	12.7	8.6
April	7.2	10.5	11.4	13.5	11.9	15.7	11.6	13.6	10.9
May	5.4	12.2	12.6	9.9	13.7	14.9	12.7	13.8	13.4
June	5.9	10.8	9.7	9.7	10.2	12.2	12.4	12.3	11.0
July	6.1	7.9	9.9	11.3	9.5	10.1	12.4	11.3	8.8
Aug.	11.5	14.3	10.1	9.6	9.7	12.0	12.3	12.2	7.6
Sept.	9.2	12.9	10.9	10.0	8.8	10.9	11.9	11.4	6.7
Oct.	10.7	11.1	11.7	10.3	11.0	10.1	11.8	11.0	10.5
Nov.	12.2	9.9	11.2	9.0	10.0	12.5	11.9	12.2	10.8
Dec.	7.4	12.0	11.5	10.5	11.8	11.2	13.6	____	____
					Avg. (Feb.-Nov.)			12.3	9.8

MONTHLY SLUDGE PUMPAGE RECORDS

TOTAL VOLUME PUMPED TO SOUTHERLY IN MG

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.	14.7	15.4	16.7	16.2	17.0	18.5	19.3		16.5
Feb.	16.0	10.4	14.8	12.4	15.1	18.5	15.5	17.0	14.7
March	16.0	16.7	17.5	16.7	13.6	19.1	16.1	17.6	16.0
April	14.0	16.0	16.3	17.8	16.5	20.4	16.4	18.4	16.9
May	16.9	17.3	18.0	14.2	19.1	20.6	17.0	18.8	20.8
June	15.5	15.9	15.6	14.4	15.6	18.2	17.4	17.8	18.1
July	13.0	11.6	16.2	16.6	15.1	16.6	17.0	16.8	15.0
Aug.	16.0	18.8	16.4	16.3	15.8	18.0	16.3	17.1	14.2
Sept.	14.3	17.5	15.2	15.4	14.3	16.9	16.3	16.6	14.0
Oct.	16.1	15.6	16.0	16.4	15.9	15.2	16.3	15.8	18.2
Nov.	16.4	13.7	17.0	16.2	14.6	18.2	16.6	17.4	18.1
Dec.	13.5	14.9	15.3	17.4	16.4	16.4	18.2		
					Avg. (Feb.-Nov.)			17.3	16.6

MONTHLY SLUDGE PUMPAGE RECORDS
AVERAGE PERCENT SOLIDS

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.	2.8	3.1	2.7	2.8	2.8	2.4	2.8		2.9
Feb.	3.2	3.4	3.2	3.0	3.0	3.2	3.2	3.2	2.9
March	3.6	3.5	3.4	3.4	3.4	2.6	3.2	2.9	3.1
April	3.6	3.2	3.9	2.7	3.2	2.7	3.5	3.1	3.5
May	3.6	3.2	3.5	2.8	2.8	2.4	2.6	2.5	2.5
June	2.8	3.1	2.6	2.6	2.7	2.5	3.0	2.8	3.0
July	3.1	2.7	2.8	2.5	2.3	2.6	2.7	2.6	3.3
Aug.	2.5	2.7	2.6	3.0	2.9	2.7	2.3	2.5	2.9
Sept.	3.2	2.4	2.4	2.8	2.5	2.7	2.5	2.6	2.5
Oct.	3.7	2.8	2.5	2.8	2.7	2.3	2.8	2.6	2.5
Nov.	3.1	2.7	2.4	2.5	2.7	2.3	2.5	2.4	2.4
Dec.	3.2	2.7	2.3	3.0	2.7	2.6	2.5	___	___
					Avg. (Feb.-Nov.)			2.7	2.9

BLOWER POWER USAGES

All Values in One Million KWHR (10^6)

	1961	1962	1963	1964	1965	1966	1967	Avg. '66-'67	1968
Jan.	1.48	1.83	1.63	1.75	1.49	1.74	2.25		1.92
Feb.	1.31	1.34	1.31	1.49	1.29	1.54	2.02	1.78	1.60
March	1.63	1.50	1.42	1.64	1.41	1.67	2.24	1.96	1.68
April	1.33	1.51	1.36	1.56	1.36	1.98	2.08	2.03	1.56
May	1.41	1.76	1.41	1.56	1.54	2.23	2.10	2.16	1.61
June	1.47	1.98	1.74	1.45	1.50	1.99	1.95	1.97	1.47
July	1.70	2.06	2.00	1.50	1.57	1.99	2.00	2.00	1.38
Aug.	2.15	2.02	1.96	1.52	1.56	2.05	2.03	2.04	1.94
Sept.	2.00	2.13	2.02	1.62	1.53	2.04	2.05	2.04	1.98
Oct.	1.41	1.66	1.84	1.60	1.64	2.19	2.13	2.16	1.50
Nov.	1.64	1.49	1.57	1.49	1.62	2.17	2.05	2.11	1.60
Dec.	1.73	1.75	1.72	1.43	1.68	2.25	2.35		
				Avg. (Feb.-Nov.)		1.98	2.06		1.63